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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

# CONTRIBUTIONS
FROM THE
SANITARY RESEARCH LABORATORY
AND
SEWAGE EXPERIMENT STATION

VOLUME IX

REPRINTED PAPERS
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INTRODUCTION

By W. T. Sedgwick, Director

The present volume constitutes the ninth of our series of contributions from the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology. Like its predecessors, it comprises reprinted papers which have appeared in the various scientific and technical journals since the publication of the last previous volume of Contributions.

The tendency toward a broadening of the scope of the investigations undertaken in this Laboratory, briefly noted in the introduction to Volume VIII, is even more strikingly emphasized in the present volume. The seventeen papers which comprise this volume may be roughly classified under the general headings: Statistical Studies of a Communicable Disease; The Bacteriology of Foods; The Study of Disinfectants; Public Health Administration; Stream Pollution and Sewage Purification, and Water Supplies.

An important investigation which has been under way for over a year and the results of which are not yet ready for publication deals with still another aspect of public health work, namely, the problem of ventilation. Some studies of the effect of the addition of ozone to a badly vitiated atmosphere have been made at the suggestion and through the support of the General Electric Company.

The major effort of the staff during the past year and a half, however, has been expended upon a study of the physical factors involved in the dissemination of heat from the body under various atmospheric conditions. This investigation gives promise of establishing certain fundamental physical laws which seem to be essentail to any proper discussion of the subject of ventilation.

A second important study which has been carried on is briefly touched upon in the paper by Professor Phelps, entitled: "An Experiment in Public Health Administration." The project which is here outlined and which will be presented in full detail at a later time has been brought successfully through its first experimental year and the organization which has been built up will without doubt be continued by the co-operating towns upon an enlarged scale of activity. Notwithstanding the obvious advantages of such a plan it is one which could hardly have been inaugurated without the support, financial and otherwise, of some such institution as ours.

The success of the enterprise has been in a very large measure due to the energetic and faithful services of Mr. Robert N. Hoyt, who has acted as Administrative Agent and Miss Edith A. Beckler, acting as Executive Secretary and Bacteriologist. Both Mr. Hoyt and Miss Beckler have been untiring in their efforts to place this experimental organization upon a satisfactory permanent basis. To Mr. Thomas F. Harris, also, who has served faithfully in the capacity of Plumbing and Sanitary Inspector and who has given much to the organization, proper credit is due.

In October of last year Professor Phelps resigned from the Faculty of the Institute and from the Staff of the Sanitary Research Laboratory, to become Chief of the Division of Chemistry in the Hygienic Laboratory, U. S. Public Health Service. His loss will be keenly felt by us, for whatever success has been achieved in our work for the last few years has been very largely due to Professor Phelps. He has been succeeded by Mr. Robert Spurr Weston, a well known sanitary engineer who brings to the work new points of view and fresh energy. Mr. Edward A. Ingham has also been attached to the Staff in the capacity of Research Assistant. The ventilation studies have been under the charge of Mr. William Grant who has been ably assisted by Mr. G. B. Zimmele.

In conclusion it is at once a duty and a pleasure to express our gratitude to the Donor who has so generously continued to support this work. We can only express our hope that our efforts in the varied lines of public health activity and our occassional contributions to human health and happiness may justify in some measure this generous endowment.

March, 1914.

TABLE OF CONTENTS

Introduction: - - - - - - William T. Sedgwick, Director

1. Is Typhoid Fever a Rural Disease? William T. Sedgwick, George R. Taylor, and J. Scott MaçNutt. (*Jour. Inf. Dis.* 11, 1912, 141-192).
2. Cold Storage and Public Health. William T. Sedgwick. (*Am. Jour. Pub. Health,* II, 1912, 825-828).
3. The Fallacy of Testing Food Materials by Animal Inoculation. William T. Sedgwick. (*Jour. Am., Med. Assoc.* LIX, 1912, 1509-1511).
4. The Bacteriology of Fermentation and Putrefaction in Relation to the Conservation of Foods. Samuel C. Prescott. (*Am. Jour. Pub. Health.* II, 1912, 833-839.)
5. The Bacteriology of Foods with Special Reference to Gelatin. Samuel C. Prescott and Charles A. Magoon. (*Am. Jour. Pub. Health.* III, 1913, 62-66).
6. The Limitations of the Phenol Coefficient in the Standardization of Disinfectants. Earle B. Phelps. (*Am. Jour. Pub. Health.* III, 1913, 53-57).
7. Report on the Division of Education and Publications of the Health Department, Milwaukee, Wis. Selskar M. Gunn and Fred W. Luening. (*Milwaukee Bureau of Economy and Efficiency. Bul.* 15).
8. Report on the Control of Communicable Disease by the Health Department, Milwaukee, Wis. Selskar M. Gunn. (*Milwakee Bureau of Economy and Efficiency. Bul.* 18).
9. An Experiment in Public Health Administration. Earle B. Phelps. (*Am. Jour. Pub. Health.* III, 1913, 867-873).
10. A Model Health Department. Selskar M. Gunn. Address before The Conference of Mayors of the State of New York.
11. The Need for a More General Co-operation between Health and Police Departments. Selskar M. Gunn. (*Am. Jour. Pub. Health.* III, 1913, 318-328).
12. The Absorption of Oxygen by De-aerated Water. (With discussion). Earle B. Phelps. (*Trans. Am. Soc. Civil Eng. Paper* 1272).
13. The Chemical Measure of Stream Pollution and Specifications for Sewage Effluents. Earle B. Phelps. (*Am. Jour. Pub. Health.* III, 1913, 524-534).
14. Bio-Chemistry of Sewage. Earle B. Phelps. (*Eighth Inter. Cong. Applied Chem., Original Communications.* XXVI, 1912, 251-260).
15. The Chemical Disinfection of Sewage. Earle B. Phelps. (*Am. Jour. Pub. Health.* II, 1912, 72-76).
16. Experiments on Disinfection of Water with Ultra-Violet Light, with a Discussion of the Laws of Disinfection. Maurice R. Scharff. (*Jour. Inf. Dis.* X, 1912, 305-320).
17. Farm Water Supplies with Special Reference to Dairy Farms. Samuel C. Prescott. (*Am. Jour. Pub. Health.* III, 1913, 892-902).

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IS TYPHOID FEVER A "RURAL" DISEASE?*

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TABLE OF CONTENTS.

1. INTRODUCTION.
2. STUDIES AND STATEMENTS OF PREVIOUS WRITERS.
3. DISCUSSION AND DEFINITION OF THE TERMS "URBAN" AND "RURAL."
4. EVIDENCE DRAWN FROM THE MORTALITY STATISTICS OF MASSACHUSETTS.
5. EVIDENCE DRAWN FROM THE MORTALITY STATISTICS OF CONNECTICUT.
6. EVIDENCE DRAWN FROM THE MORTALITY STATISTICS OF NEW HAMPSHIRE.
7. RECAPITULATION AND CONCLUSIONS.

1. INTRODUCTION.

There has long been a widespread belief that typhoid fever is a "rural" disease, i.e., a disease having its natural habitat in the country. On the other hand, bacteriology and epidemiology have proved that typhoid fever is a disease of contact, of crowding, and of infected food and drink—conditions far more common in city than in country. Obviously, so sharp a contradiction between a condition reputed to exist, and a condition required by theory, calls for careful investigation.

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* Received for publication May 2, 1912.

Paragraphs in the newspapers and magazines often advise persons about to visit the country to beware of typhoid infection, implying if not affirming that the dangers of such infection are greater in the country than in the city. And when the annual autumnal excess of typhoid fever, which occurs almost everywhere in northern latitudes, draws attention to this disease, it is frequently asserted, not only by newspaper and magazine writers, but also by medical men—and sometimes even by sanitarians—that this excess is due to the fact that many city dwellers have recently returned from vacations in the country, and have brought with them either typhoid fever or the germs of typhoid fever.

This explanation of some cases of autumnal typhoid is so obviously true that the forbidding term "vacation typhoid" has been coined and widely circulated and is now often accepted at its face value, even by persons who have given attention to the causation of typhoid fever, as satisfactorily accounting for most of the regular autumnal excess of that disease. This modern notion of "vacation" typhoid, moreover, is closely connected with an older theory that typhoid fever is pre-eminently a "rural" disease, a doctrine long maintained on good grounds by excellent authorities and powerfully supported by theories—such as Murchison's pythogenic theory—of the spontaneous origin of fevers like typhoid in manure-heaps, decaying organic matters, and filth of various kinds.

The rise of bacteriology and the decade of the great pathological discoveries have, however, disproved Murchison's and similar theories, and the simple faith of a former generation in filth and "fomites" as birthplaces for disease germs has been proved to be groundless. Meantime, the importance of contact, of carriers, of crowding, of promiscuity, and of public supplies of all sorts as sources and vehicles of infection, and the value of isolation of persons and supplies and of the absence of contact, of crowding, and of promiscuity as safeguards against infection have become generally admitted and recognized, until it is today almost impossible to believe that the dangers of infection in the sparsely settled country are anywhere near as great as in the crowded city, or *a fortiori* that typhoid fever is today really a "rural" disease. This fact is strengthened and supported by considerations of bacteriology and epidemiology, for it is today impossible to believe that the germs of typhoid fever which must pass from person to person by contact or in food or drink, can be as widely or as effectively distributed by isolated carriers, isolated wells, or isolated milk supplies in rural districts, as by the city carrier necessarily coming into contact with far more people, or the public water or milk supply of the city, reaching as it does simultaneously hundreds or thousands, instead of units or tens or twenties.

And yet it is still often affirmed that "typhoid fever is a rural disease" and implied if not stated that city people who spend vacations in the country are more liable to contract typhoid fever there than they would be if they stayed in the city. We have here therefore, as already said, a flat contradiction between conditions reputed to exist and conditions according to modern ideas to be expected; and it is this contradiction which has seemed to us to require explanation, and has induced us to examine into the facts and to prepare the present paper.

The question at issue is simply *whether, in proportion to the population, typhoid fever is more prevalent over rural or over urban areas;* and for an answer we have turned to the mortality statistics of Massachusetts as a state having trustworthy records and one with which we are personally familiar. These statistics we have examined from various points of view with special reference to the question at issue. For control, we have made a similar though less minute study of the mortality statistics of a more rural contiguous state, New Hampshire, as well as those of Connecticut, another contiguous state which for various reasons is also instructive in this connection. Brief references have likewise been made to the mortality statistics of foreign countries, such as England and Wales, Scotland, and Germany.

Before presenting the methods and results of our statistical studies, we shall consider at some length the rise and the present state of opinion relating to typhoid fever as a rural disease; and in another section, also in some detail, the common employment of the terms "rural" and "urban," as well as their true sanitary significance and proper scientific usage.

2. STUDIES AND STATEMENTS OF PREVIOUS WRITERS.

As far as we are aware, the earliest statistical study which led to the conclusion that typhoid fever is a rural disease was made by Dr. George Derby, secretary of the then newly organized State Board of Health of Massachusetts, and published in the Report of that Board for 1871. Dr. Derby's paper is entitled "The Causes of Typhoid Fever in Massachusetts" and is an elaborate statistical research covering the decennium, 1859–68. Dr. Derby's studies were based upon the mortality statistics of typhoid fever in all the "towns" of Massachusetts for that period. Because of the fundamental character of this paper, and the probability that from it has very largely come the present doctrine of typhoid fever as a rural disease, we shall quote from it somewhat freely:

"The first thing which strikes us on looking over this table is the apparently greater mortality from typhoid in the small towns. How great this difference is will appear from the following comparison:

TABLE SHOWING RELATIVE MORTALITY FOR TEN YEARS FROM TYPHOID FEVER IN PERSONS ABOVE FIVE YEARS OF AGE, IN THE LARGER AND SMALLER CITIES AND TOWNS.

	Population 1865 (All Ages)	Total Deaths from Typhoid in 10 Years	Average Number Persons Living Each Year to One Death	Average Number Deaths Each Year to 1,000 Persons Living
147 cities and towns of more than 2,000 inhabitants	1,044,294	7,888	1,323.90	0.755
184 towns of less than 2,000 inhabitants	213,468	2,539	840.75	1.189

"There can be no doubt that typhoid in Massachusetts is a disease of scattered communities rather than of crowded towns, of rural rather than of urban districts. In spite of the smaller mortality from all causes, typhoid is more destructive in the farming towns than in the manufacturing towns and the large cities" (pp. 118, 119).

Again, later in the same paper:

"Everyone familiar with the state knows that there is a very large number of towns with a population of from five to ten thousand, compactly built, with no water-supply except from wells, and no means of disposing of excrement except by privies, and we know from the registration returns that the people of these towns are more free from the pest of typhoid in proportion to population than the inhabitants of agricultural districts" (p. 166).

Again, from the letter of a Boston correspondent:

> "A very considerable number of the cases of typhoid treated in Boston during the autumn originates in the country and at seaside places where families from the city have passed the summer" (p. 128).

This able and thorough study thus arrives at a definite conclusion that typhoid fever is chiefly a disease of communities of less than 2,000 inhabitants. Here is apparently one of the main sources of the "rural typhoid" doctrine.

The next study of the kind, so far as we have been able to discover, was a thorough and detailed statistical research, published by Dr. Samuel W. Abbott in the Report of the State Board of Health of Massachusetts for 1891, as a part of a paper on "The Geographical Distribution of Certain Causes of Death in Massachusetts." The first part of the section on typhoid fever, which covers the twenty-year period, 1871–90, deals with the relation of prevalence to density of population, by counties. The following summary table is an abridgment of that given on p. 822 of the report.

Counties Grouped According to Their Density of Population	Average Acres to Each Person	Mortality Rank from Typhoid Fever. The State = 100
I. County in which there is less than one acre to each inhabitant	0.07	91
II. Counties (5) having more than one but less than four acres to each inhabitant	2.10	101
III. Counties (8) having more than four acres to each inhabitant	6.40	107

Dr. Abbott concludes from this table that:

> "The mortality from typhoid fever does not depend upon the density of population as the principal favoring condition for its spread. The most densely settled metropolitan district had a comparatively low mortality rate from this cause, while the group of sparsely settled counties had an average high ratio of mortality from typhoid fever. . . . ."
>
> "Estimating the mortality of the densely settled districts as 1,000, the mortality of these three groups from typhoid fever was as follows:

The *dense* districts	1,000
The *medium* districts	1,109
The *sparse* districts	1,175

The analysis thus summarized has apparently furnished a basis for the doctrine that typhoid fever is chiefly a rural disease, because it is here shown, under the conditions considered, to be more prevalent in the *sparsely* settled counties. But while density studies applied to small areas—as those of a New England "town"—may be reliable, the results from the comparatively large areas of counties are, in the light of the considerations presented in section 3 of this paper, open to serious criticism. In the county all grades of urban and rural life are included and merged together and *general* density figures cannot give any adequate indication of that local distribution of population which is the *sine qua non* of a study of urban vs. rural conditions.

Dr. Abbott, however, later in his study, does take up the separate towns considered with reference to density of population, and this mode of attack we believe to be much more effective than that just quoted. He bases his observations upon a table, similar to the one presented by Dr. Derby for 1859–68 in which the towns of Massachusetts are arranged according to their typhoid death-rates.

"An examination of the extremes reveals no very striking characteristics. But one town, Gosnold (the smallest in population), had no deaths from typhoid fever during the twenty years. This town comprises the Elizabeth Islands, lying at the mouth of Buzzard's Bay. Its population in 1880 was 152.

"The twenty towns having the lowest rank in the list are scattered throughout the state in ten of the counties, and, with the exception of one of the smaller cities (Waltham), are small towns. Twelve of this number had less than 1,000 inhabitants in each in 1880. There does not appear to be any point of special significance relative to these twenty towns.

"Of the twenty towns which hold the highest position upon the list, seventeen are in the four western counties and the western border of Worcester County. Dalton, with the highest ratio, is a manufacturing town (paper mills) among the Berkshire Hills, lying at an elevation of more than 1,000 feet above the sea-level. Ware, Brookfield, Great Barrington, and Westfield are also manufacturing towns of western Massachusetts. Ten of the remaining towns are small agricultural towns, having a population in each of less than 1,000, and their position may hence be regarded as having but little significance.

"The city of Holyoke, which had 498 deaths from typhoid fever in the twenty-year period, and ranked 203 in this list as compared with the state (100), is a manufacturing city of rapid growth. Its population in 1870 was 10,733; in 1880, 21,915, and in 1890, 35,637. The principal industry is the manufacture of paper" (p. 823).

A classification of towns by density of population is thus described:

"For the purpose of making a more intelligent classification I have therefore classified the towns into two general divisions of manufacturing or densely settled towns, and agricultural or sparsely settled towns.

"The former embraces 87 municipalities, including all the 28 cities. None of this number had less than 2,000 inhabitants in each, and only 10 had less than 4,000; and each of these smaller towns had one or more villages having a comparatively dense population living in a district of limited size. The average population of each municipality in this group by the census of 1880 was 15,434. Most of them have a steadily increasing population, a large proportion of which consists of immigrants, either of European nativity or from the British North American provinces. In many of the towns of this class there is a rural population of considerable size living in those portions outside the more densely settled villages. The actual increase in population in the rural towns, for the period of twenty years, between the census of 1870 and that of 1890, a period nearly coincident with that under consideration, was 11¼ per cent, while that of the larger or manufacturing and urban districts was 70 per cent.

"The other group, of agricultural towns, 259 in number, has but few towns having 3,000 in each, and the average population of each in 1880 was 1,700. Their population is distributed over an average area of nearly 30 square miles for each township. The principal occupation of the people of these towns consists of dairy farming market gardening, and other branches of agriculture. A few of these towns are summer resorts, either upon the sea-coast or in the inland region. Some of the towns of this general class have increased slightly in population in the past twenty-five years, many have remained stationary, and a considerable number have slowly decreased. . . . . The population of the first group in 1880 was 1,342,782, and that of the second group, 440,303" (pp. 762–63).

"Dividing the towns into [this] more accurate classification, without regard to county lines, the towns which may be considered as having a dense population had a mortality rate of 5.15 per 10,000 annually from typhoid fever, while the remaining towns had a mortality rate of 5.54 per 10,000" (p. 823).

This finding, based as it is upon much smaller areas than the counties, approaches much more nearly the study of purely local conditions which alone is instructive for our present purpose, and should therefore be accorded much greater weight.

Dr. Abbott has later stated that it is among that portion of the population not supplied with public water that "typhoid fever largely occurs."[1]

Finally, Dr. Abbott compared the mortality in towns, with the results obtained by Dr. Derby for 1859–68, finding that the same general relations between urban and rural—manufacturing and agricultural—communities still held good in the later period. There is, however, one important difference, viz.:

"The cities which had specially high death-rates from typhoid fever in the later period (1871–90)—Holyoke, Lowell, Lawrence, Fall River and Chicopee—held an intermediate position in 1859–68; and it was not until after a polluted water-supply had been introduced in Lowell and Lawrence that their death-rate from typhoid fever reached an unusually high figure."

---

[1] Reference Handbook of the Medical Sciences, 1904, 8, p. 254.

The researches of others which we shall summarize are based upon arbitrary statistical divisions of communities into two crude groups of "urban" and "rural." The next in point of time that we have been able to discover is that of Ernst Bolin, based upon the official statistics of Sweden and published at Stockholm in 1893 as a Doctor's thesis presented to the medical faculty of Upsala University, entitled *Tyfoidfebern i Sverige.* The author gives for *närv-* and *hjärnfeber* taken together (equivalent to typhoid fever) the following figures:

	DEATH-RATES PER 100,000 OF POPULATION		
	Towns*	Country Villages†	Whole Kingdom
1876–1880	53	31	34
1881–1885	34	26	27
1886–1890	24	22	23
1876–1890	36	26	28

* The *towns (städer)* are distinguished in the official statistics as a separate group. According to the Census of December 31, 1890, there were at that time 92 *städer* with an aggregate population of 899,698. Of these 10 had populations of less than 1,000; and 21 between 1,000 and 2,000. It is obvious that the proportion of the total population contributed by these towns of less than 2,000 is inconsiderable (about 5 per cent), and *for present purposes the Towns group may be taken to represent places of over 2,000 population.*

† The *country villages (landsbygden)*, though including a few places of over 2,000, *practically represent rural communities of less than that figure,* since the population of the few larger places is relatively very small. "Among the places which are not, in law, recognized as towns, there are a few which have a total population of more than 2,000 souls. Some of these places are suburbs of towns; . . . . others are what are called *köpingar* (boroughs), which, from a legal point of view, are something between town and country and, finally, there are some industrial and business places, of which Malmberget . . . . and Trollhattan, with 7,000 inhabitants each, are about the largest" (*Sweden, Its People and Its Industry,* pub. by order of the Swedish Government, 1904, p. 103). The rural region or *landsbygden* comprised in 1890, 3,885,283 inhabitants, including 20 *köpingar* (boroughs). Of the latter, 12 were under 1,000 and 6 from 1,000 to 2,000; the remaining two having 2,205 and 2,075. Thus it is evident that the rural character—as assumed for small communities—of the country villages group is not seriously altered by the inclusion of the few places of over 2,000 population.

Taking *närvfeber* alone (as the term *hjärnfeber* is subject to inexactness), the figures are as follows (p. 56):

	DEATH-RATES PER 100,000 OF POPULATION		
	Towns	Country Villages	Whole Kingdom
1876–1880	52	25	29
1881–1885	32	25	27
1886–1890	23	22	22
1876–1890	34	24	26

The conclusion is reached that:

> "Typhoid fever, for the entire period, 1876–90, was more general in the towns than in the country villages" (p. 58).

The same conclusion is reached when the proportion of typhoid deaths to the whole number of deaths from all causes is considered (p. 62).

The division here is at a population of 2,000. How far places in Sweden of less than this number of inhabitants represent typical rural conditions we cannot presume to say. The higher group of "towns" is probably a heterogeneous mixture of urban and rural.

To return to American studies, Dr. F. C. Curtis published in the Bulletin of the New York State Department of Health, October, 1900, a statistical study on the distribution and etiology of typhoid fever in that state. Though it was not the object of his study to draw conclusions as to urban and rural typhoid, data are given of 20 of the largest cities in New York state, and, by contrast, of small rural towns, the communities falling between these two groups being omitted. The following is an abstract of the principal table presented:

AVERAGE DEATH-RATE FROM TYPHOID FEVER, 1890–1899, IN 20 CITIES OF 20,000 AND OVER POPULATION.

Low Prevalence	Rate per 100,000 Population
New York	17.0
Yonkers	16.0
Kingston	20.0
Utica	20.0
Auburn	25.0
Rochester	26.0
Moderate Prevalence	
Oswego	27.0
Buffalo	31.0
Syracuse	35.0
Newburgh	37.0
Excessive Prevalence	
Poughkeepsie	42.0
Amsterdam	52.0
Binghamton	52.0
Troy	55.0
Elmira	55.0
Very High Prevalence	
Watertown	80.0
Niagara Falls	80.0
Albany	86.0
Cohoes	90.0
Schenectady	100.0
Rural towns (800)	23.0

The "rural towns" mentioned at the end of this table appear to be a group of the smallest communities arbitrarily set apart after the cities, villages, and more populous towns are taken out. The group is thus fairly representative of the small agricultural villages and hamlets, as well as of the purely agricultural regions. There is no exact criterion of population, but, to judge from other statistical tables of the Bulletin, very few of the communities are over 2,000, while all places under that figure are included. The indication is that genuinely agricultural or rural conditions characterize this group, which has a typhoid death-rate below all but four of the large cities. Dr. Curtis comments on the table as follows:

> "Some zymotic diseases belong especially to the cities; evidently typhoid fever does not of necessity. The maritime district is almost wholly urban and its annual death-rate of 17.0 and ratio of 0.86 per cent of total mortality is the lowest; and including more than half the entire population reduces the state death-rate to 24.0, which without it would be 31.0. Neither is it on the average a disease of high mortality in rural towns, for they have a constant mortality of from 22.0 to 25.0 per 100,000 population, and districts with the smallest so-called urban population approach nearest to the rural rate" (*Ann. Rpt. N.Y. State Bd. of Health,* New York, 1900, pp. 429–30; also in Bulletin for October, 1900).

The comparison here made between large cities and small "rural towns" we believe to be valuable, so far as it goes. It is to be noted that the indication of these statistics that the "rural towns" are comparatively low in typhoid is the reverse of the conclusions arrived at by Drs. Derby and Abbott in Massachusetts.

The following extracts indicate the statistical analyses—based upon a division of communities into "urban" and "rural," above and below the 8,000 population mark respectively—published by the U.S. Census since 1890. The misleading character of this mode of division, which will be discussed in section 3, must be borne in mind.

> "Typhoid fever was slightly higher in 1900 in the rural districts (25.5) than in the cities (25.3), which is the reverse of the case in 1890, when the rate in the cities was 39, and that in the rural districts 31.4" (*Census of 1900,* 3, p. cxlv).

	Number of Deaths from Typhoid Fever per 100,000 of Population					
	Annual Average	1900 to 1904				
		1900	1901	1902	1903	1904
Cities in registration states.....	25.8	28.5	26.5	25.9	24.6	24.0
Rural part of registration states	27.8	34.6	28.8	27.0	24.7	23.8

(*Mortality,* 1900 to 1904, excerpted from table on p. xxi.)

> "Comparing the rural and urban districts of the registration states it will be seen that the mortality from typhoid fever was greater in the rural districts than in the cities in each year except 1904, in which it was very slightly greater in the cities" (*ibid.*, p. xxii).

In the *U.S. Mortality Statistics* for 1907 the typhoid fever rates per 100,000 for 1906 and 1907 are given as follows:

	1906	1907
Cities in registration states	34.2	31.7
Rural part of registration states	28.6	26.0

Among the most detailed studies on rural typhoid which we have found is that contained in a paper by Dr. John S. Fulton, published in the Report of the State Board of Health of Maryland for 1903, and entitled "Typhoid Fever: Some Unconsidered Hindrances in Its Prophylaxis." This research is probably the most thorough and authoritative hitherto made. It is, however, unfortunately based almost entirely upon the arbitrary and (for this purpose) misleading classification of the U.S. Census, and the real question of rural typhoid fever, accurately speaking, is hardly touched upon by any portion of the study. We shall briefly summarize that portion of the paper in which the question now at stake is taken up, and from p. 61 may quote the following introduction:

> "The belief that typhoid fever is more common in close communities, and that its incidence is heaviest in cities, has its place in the medical mind by a sort of common consent. The grounds of the belief have not been examined, if, indeed, they have been stated. The late Colonel George Waring said in 1878: 'Typhoid is peculiarly a disease of the country rather than of the town.' No similar statement, I believe, is made by any American medical author; but the opposite view, that typhoid is peculiarly a disease of cities, is expressed in the most recent editions of at least four American textbooks on medicines.[1]
>
> "Typhoid fever makes its most striking demonstrations in cities, and the definite influence of sanitary works on its prevalence has made the typhoid rate the accepted index of municipal hygiene. Typhoid fever has, nevertheless, at the present time and in this country a heavier incidence on small communities and rural districts, and probably this has been the case for a long time; for sanitary works have neither such excellence nor so wide employment in American cities as to give urban populations in general good defense against typhoid. On the contrary, the conditions of American cities with respect to water supply and disposal of waste might be expected to produce a constantly higher typhoid mortality than is experienced under rural conditions."

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[1] We have been unable, after a careful search through the textbooks of Osler (1901), J. C. Wilson (1896), H. M. Lyman (1892), William Gilman Thompson (1902), and others, to verify this statement.

The following fields for statistical evidence, based upon the Census division into "urban" and "rural," are then considered in detail: registration area, "grand groups" of the Census, and five "grand groups." The principal result of the study is summarized in the table quoted below and prefaced as follows:

> "Some doubt may be admitted as to whether these grand divisions can fairly be compared. If the United States be divided into state groups on the basis of the distribution of the population between town and country, we can eliminate to a great extent the influence of latitude and longitude."

	Average Percentage of Rural Population	Average Typhoid Fever Death-Rate per 100,000
Five states in which the urban population was more than 60 per cent of the total	30	25
Six states in which the urban population was between 40 per cent and 60 per cent	49	42
Seven states in which the urban population was between 30 per cent and 40 per cent	67	38
Eight states in which the urban population was between 20 per cent and 30 per cent	75	46
Twelve states in which the urban population was between 10 per cent and 20 per cent	87	62
Twelve states in which the urban population was between 0 and 10 per cent	95	67

The above groups are constituted as follows, in order: *Five states:* Massachusetts, New York, New Jersey, District of Columbia, Rhode Island. *Six states:* Connecticut, Pennsylvania, Delaware, Maryland, Illinois, California. *Seven states:* New Hampshire, Ohio, Michigan, Wisconsin, Missouri, Colorado, Washington. *Eight states:* Maine, Indiana, Minnesota, Louisiana, Montana, Wyoming, Utah, Oregon; *Twelve states:* Vermont, Virginia, South Carolina, Georgia, Florida, Tennessee, Alabama, Texas, Iowa, Nebraska, Kansas, Kentucky. *Twelve states:* West Virginia, North Carolina, North Dakota, South Dakota, Mississippi, Indian Territory, Oklahoma, Arkansas, New Mexico, Arizona, Nevada, Idaho.[1]

"The experience of Maryland supports the general indications of these figures. There is but one large city in the state. The inhabitants of Baltimore are half of the total population of the state. There are but two other towns having as many as 8,000 inhabitants. It may be fairly said that the population of the state is equally divided between rural and urban conditions. The ratio of typhoid mortality is 1 to 2.5 in favor of Baltimore, a poorly sewered city, supplied with unfiltered water from an extensive and unprotected watershed."

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[1] In this part of the study on p. 63 are several misprints or errors. In one case 12 states are mentioned with the names of only 8; in another, 12 states are mentioned with the names of only 11. Several of the figures given do not agree with those given in the statistical tables printed at the close of the paper.

The study closes with a tabulation of the cities of the United States arranged in groups according to population, showing that the typhoid mortality rises somewhat as the populations diminish. But the smallest group given has an average population of over 12,000, so that rural communities are not concerned. A group of almost eight million people remaining over and above the cities, and called 95 per cent rural, shows a higher mortality than any of the city groups.

Dr. Fulton concludes:

> "The infection is more heavily seeded in small communities, and the propagation of the disease is in general from the country to the town, rather than from town to country. The explanation of this fact is probably found in the greater care given to the disposal of human excrement as communities grow more populous" (p. 67).

As evidence of the strong persistence of the rural typhoid theory as above elaborated, it is interesting to note that a recent authority, George C. Whipple, cites Dr. Fulton's study with the remarks:

> "Contrary to what many people suppose, typhoid fever is more largely a rural disease than an urban disease, meaning by rural small communities in distinction from large communities" (*Typhoid Fever*, New York, 1908, p. 112).
>
> "The autumnal increase of typhoid fever in cities is sometimes referred to as 'vacation typhoid,' the idea being that it is due to patients returning sick from the country. This theory is based on the fact that typhoid fever is at present chiefly a rural disease, and so far as this goes it is correct" (*ibid.*, p. 127).

Mr. Whipple thus concurs in Dr. Fulton's conclusion so far as *distribution* of typhoid fever is concerned. In regard to its *propagation* he goes on to say:

> "But the notion of 'vacation typhoid' has been very much overworked, and, as a matter of fact, it does not to any very material extent, account for the summer and autumn increase of typhoid fever in the large cities. In Washington it was estimated that during the summer and autumn of 1906, 85 per cent of the cases were contracted within the city, and studies of imported cases in other cities have given similar figures" (*loc. cit.*).

By way of further comparison, the statistics of the Registrars-General of England and Wales, and of Scotland may appropriately be cited at this point. For Scotland we quote the following mortality figures for typhoid fever since 1899:

DISTRICTS	CONTAINING PLACES HAVING POPULATIONS	ENTERIC DEATH-RATES PER 100,000 POPULATION							
		1900	1901*	1902	1903	1904	1905	1906	1907
Scotland		15	16	12	12	9	8	9	8
Principal town districts	More than 30,000	14	18	11	14	10	7	8	7
Large town districts	10,000 to 30,000	19	17	18	15	11	16	17	15
Small town districts	2,000 to 10,000	17	18	11	11	8	7	7	6
Mainland rural districts	Under 2,000	12	11	11	9	7	5	6	5
Insular rural districts	Under 2,000	10	12	16	11	10	8	11	8

* Census year.

Populations of groups, estimated for 1907, were approximately as follows: principal town districts, 2,178,000; large town, 603,000; small town, 964,000; mainland rural, 919,000; insular rural, 113,000.

The division into "town" and "rural" is made at 2,000 population; and here, as for Sweden, we cannot venture to say whether communities below that figure probably fairly represent rural conditions. The town groups are presumably a mixture of rural and urban, with the latter predominating.

For England and Wales the figures are less detailed, but represent large populations. The following are typhoid fever death-rates per 100,000 of population (corrected for age and sex distribution of population):

England and Wales	Average 1898–1902	Average 1903–7	Year 1908
Urban counties	19.3	9.9	8.4
Rural counties	10.4	6.8	5.6

The basis for these figures is indicated by the following from the report of the Registrar-General for 1901:

> "On examining the local distribution of enteric fever it is found that, generally speaking, its mortality varies as the area affected contains either a large or a small proportion of urban population. For this reason a selection from among the counties of England and Wales has been made so as to show (*a*) in one list certain counties that are chiefly urban in character, and contain most of the industrial centers, and (*b*) in another list certain counties that are exclusively rural, or that contain a few small towns which although technically styled urban, nevertheless partake of that character to a slight extent only" (p. xlix).

The total population of these two selected groups comprises about two-thirds of the total population of England and Wales. The division is evidently arbitrary, but by no means blindly so. Inasmuch as a definite attempt is made to distinguish agricultural (i.e., small and segregated) communities from industrial (i.e., large and concentrated) communities, the division is much superior to statistical separations made solely on the basis of populations.

English and Scotch statistics thus agree in indicating for the smallest communities, i.e., the segregated agricultural communities, relatively low typhoid mortality. The excessive mortality in the "large town" districts of Scotland is, moreover, especially noteworthy.

As a matter of record the following references are also appended:

A. Dr. John H. McCollom, in a study (1893) of typhoid fever in Boston, by wards, attributed a slight increase in the frequency in Ward 4, a part of Charlestown, in all probability to "the fact that in this locality the majority of the population leave the city for a greater or less length of time during the summer months, and contract typhoid fever in the country."[1]

B. "In England and Wales . . . . [typhoid fever] destroys more lives in proportion to population in towns than in the country. . . . . [In the United States] it is more prevalent in country districts than in cities, and, as Fulton has shown, the propagation is largely from the country to the town. . . . . In Germany the larger cities have comparatively little typhoid fever. . . . ."[2]

C. In a review of an investigation of typhoid fever at Ipswich, England, by Dr. A. M. N. Pringle, medical officer of health, who ascribed a diminution of typhoid fever in that town to the abolition of the "midden" system in favor of sewerage—a writer in the *Boston Transcript* for October 13, 1909, says:

"There is an important lesson for this country in this investigation, since it shows in Ipswich the typhoid conditions under the same kind of sanitary arrangements that obtain in the rural districts here. The autumnal rise in typhoid is so well marked here and its underlying reason is so clearly understood that it has been termed 'vacation typhoid.' It is a feature in northern American cities, and Dr. Pringle's article points directly to what is without doubt the most constant maintaining factor in the case."

D. "There is reason to believe that the term 'vacation typhoid' which has come into use is far from being without meaning."[3]

E. At the New York State Conference of Health Officers held at Rochester, November, 1909, U.S. Surgeon L. L. Lumsden stated:

"In the United States the rate of prevalence of typhoid fever is higher in the rural sections than in the cities and a city, surrounded by and obtaining its food supplies from a section of the country in which the typhoid rate is high, will have a high typhoid rate."[4]

F. A good example of current newspaper opinion is the following which appeared in an editorial in the *Boston Globe*, June 28, 1911:

"Typhoid and other fevers afflict humanity most immediately after summer vacations and are due generally to the insanitary conditions which have surrounded those who have been seeking pleasure and health away from home."

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[1] *Boston Med. and Surg. Jour.*, 1893, 129, p. 296.

[2] William Osler, *Practice of Medicine*, 1910, p. 58.

[3] *Bull. N.Y. State Dept. of Health*, 1909, p. 248.

[4] *Ibid.*, 1909, p. 266.

The quotations given demonstrate without need of further comment the confusion of opinion and the obscurity in which the whole subject stands. When authorities differ, some affirming and others denying a widely prevalent opinion that typhoid fever is a "rural" disease, and is spread chiefly from country to city, a careful investigation is evidently required to settle the question by determining the facts.

3. DISCUSSION AND DEFINITION OF THE TERMS "URBAN" AND "RURAL."

The terms "urban" and "rural" are often used in a vague and general sense while at other times an apparent precision is introduced by arbitrary statistical definition. Thus the U.S. Census division of communities into urban and rural above and below the 8,000 population mark, which has been taken as a basis for study by Fulton and others, is a purely arbitrary line of demarkation and obviously not especially preferable to some other and perhaps lower figure.[1]

Nevertheless, as a basis for sanitary studies, it is necessary to bring together, if possible, and to compare, populations living under either closely corresponding or else strongly contrasting sanitary conditions; and this it is by no means easy to do. There are, for example, great differences in many respects in living conditions and therefore in sanitary conditions between (1) isolated farmhouses, (2) country villages, and (3) the somewhat larger and often compact communities which frequently cluster about a mill or a factory employing a hundred or several hundreds of operatives. Yet hundreds of all three of these and of many other classes are included in the "rural" group of the U.S. Census among communities having fewer than 8,000 inhabitants. Obviously, typhoid fever might prevail in group 3 and at the same time be very scarce in group 1; and yet it is often spoken of as "a rural disease" and ought therefore to be more abundant in the sparsely settled country than in the factory village of denser population.

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[1] Since the above was written the United States Census (1910) has set the definitive figure at 2,500, which appears preferable to the old practice. We have, however, thought it wise to let our original discussion stand unaltered; first, because the Census division at 8,000 has been generally accepted as a basis by Fulton and others; and secondly, because we have endeavored to develop the general principle that *any* such arbitrary division of population, unless taken in the roughest sense, is misleading.

The sanitary conditions in a community having one, two, or three thousand inhabitants, and technically called "rural," may and often do more closely resemble those of the city than they do those of the country farmhouse or the sparsely settled hamlet. Such places may, for example, have public water-supplies, and sewerage systems, and if built closely around mills or factories, may possess typical city congestion and tenement-house crowding. Other communities, on the other hand, which under the Census division are also called "rural" may be in fact mill towns or factory towns which have gone beyond the stage of country villages but have not arrived at what are essentially city conditions. This state of development means that most of the dangerous conditions of the city have arrived, while public water-supply, sewerage, and adequate sanitary supervision have not yet been secured. "The state of change" has been called "the state of danger," and the dictum certainly applies in community life. Congestion is characteristically a city evil, but it is no less an evil when connected with the overgrowth of small mill or factory communities where it may exist in as great or even greater degree than in larger centers of population. Such communities, we repeat, are often denominated "rural" under any arbitrary classification which takes no account of the actual characteristics and distribution of housing, crowding, and other *sanitary* conditions of the various communities in question.

The definition used by the Census is, moreover, never exact, as the terms "urban" and "rural" are used without qualification. The inexperienced reader will often suppose these arbitrary statistical terms to be used in a true sense and will be misled as to the phenomena involved, while even the experienced reader may take the distinction to be the trustworthy result of careful analysis of conditions. Thus, while convenient for certain purposes, the terms may lead to erroneous confidence in a meaning which does not exist.

Other studies, e.g., those of the New York State Board of Health (see sec. 2) make no exact distinction, but arbitrarily separate out two groups, as by the criterion of incorporation or general order of magnitude of population. In the studies of Bolin, in Sweden, and of the Registrar-General of Scotland, the division into rural and urban is equally arbitrary, in the former case by political, in the latter by sanitary, districts; although by special inquiry we have found that the lines in both these two cases are drawn at about 2,000 population.

In the study by Dr. S. W. Abbott, published in the Report of the Massachusetts State Board of Health for 1891, a different method is used, various degrees of density of population by area being used as a basis.

In no case, however, so far as we have been able to discover, has any detailed analytical description of the nature of the "rural" and "urban" populations studied been given,[1] a fact to which much vague thinking on this question may be attributed. Nor has any classification by degree of rural conditions, into more than two crude classes, been made. Rigid definitions of the terms must, in view of the complex character of the conditions, be untrustworthy if not misleading, yet it is nevertheless essential that the general conditions connoted by them be kept in mind.

The term "rural" (derived from the Latin *rus*, country) signifies strictly "of or pertaining to the country as distinguished from a city or town." A secondary meaning at once suggested by the primary one is "agricultural"—the first describing the place, the second the occupation of the inhabitants. It becomes necessary, therefore, to rule out from any group of rural communities all having essentially "city" conditions. The chief of these conditions, from the epidemiological standpoint, are: (1) the congestion characteristic of centers of population; and (2) systems for public convenience, such as public water-supplies, public sewerage systems, public milk-supplies, etc. City life is a state of concentration and even more or less congestion; country life of isolation or segregation. Consequently a purely rural area is one in which the dwellings are more or less widely separated and, instead of being dependent on the systems of public convenience mentioned as characteristic of the city, form in that respect wholly independent and disconnected units. Such a condition, strictly speaking, rarely exists, for everywhere little clusters of dwellings, or "hamlets," tend to spring up. It is, however, approximated in all really country life for even where there is community in certain sanitary conditions, such as, for example, a common source of provisions (many of which are, however, eaten only after cooking), or through a common school or a common church, the great sanitary factors, such as water-supply, milk-supply, and sewerage, remain practically separate, each dwelling having its own well, its own dairy, and its own privy or cesspool. Personal contact is also reduced to its lowest terms, and is largely confined to families. It is, then, between these two opposing conditions of *concentration* or *segregation* of homes or families that the study of urban vs. rural typhoid must be made; and it is only in the sense of *segregation in the country* that the term "rural" should be used for sanitary studies.

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[1] A partial exception to this statement is found in the *Mass. State Census*, 1905, I, p. xxxii, where dissatisfaction with the U.S. Census division is expressed and a subdivision into rural (under 5,000), semi-urban (5,000–8,000), and urban (over 8,000) is made.

In given instances the conditions are usually complex. Congestion typical of city life may exist in one corner of a community otherwise rural in character, e.g., in a small factory village which though crowded lacks the city characteristics of common water-supply, sewerage, and milk-supplies. On the other hand, the suburbs of a city often have common water-supplies, milk-supplies, and sewerage, and yet approach rural conditions as to segregation of dwellings, absence of congestion, and of personal contact. In no instance can hard and fast lines be drawn, but the principle separating the two groups holds good. For statistical purposes it might be wished that the sanitary phenomena of large numbers of segregated farms could be studied and contrasted with those of typical cities, but practically, it is convenient to take separate towns (in New England), as the smallest units statistically available, and group them together for study according to their population.

To recapitulate, it is plain that any arbitrary division of population into "urban" and "rural," statistical or otherwise, which leaves out of account the facts we have mentioned is misleading. To conduce to a clear understanding of the conditions to be contrasted, we have framed the following characterizations of urban and of rural communities. Hereinafter we shall use the terms solely in these senses, except as otherwise indicated:

A rural community is one characterized by sparsity of population, with segregation of a few families upon a large area; it is accordingly one in which the chief sanitary factors of water-supply, milk-supply, and sewerage are entirely separate for each household, and in which personal contact and association between the members of different families are reduced to their lowest terms.

An urban community is one characterized by density of population with concentration of many families upon a small area; it is therefore one in which some at least of the chief sanitary factors are common to many households, and in which much personal contact and association exist between the members of different families.

4. EVIDENCE DERIVED FROM THE VITAL STATISTICS OF THE STATE OF MASSACHUSETTS.

For the purpose of answering the apparently simple question which forms the subject of this paper, we have made a careful analytical and statistical study calculated to disclose the relative amounts of urban and rural typhoid fever, first, and especially, in Massachusetts, and afterward in the adjoining states of Connecticut and New Hampshire. Moreover, since urban and rural conditions invariably merge each into the other, and since the main object of our study has been to determine how the relative proportions of each affect the prevalence of typhoid fever, any merely rough or arbitrary division into these two classes is not enough. Our studies deal instead with a considerable number of *community groups* and have been designed to be in this respect much more searching, than any, as far as we know, hitherto made.

For several reasons we have chosen for intensive study the mortality statistics of the state of Massachusetts: first, because in Massachusetts we have statistics of approved accuracy covering a period of many years; in the second place, because Massachusetts either has been or now is the home of all three of the authors, and is therefore personally known to them in much detail; in the third place, both agriculture and manufacturing have long been and still are of great importance in Massachusetts, so that both the segregative influences of American agricultural life and the concentrative influences of industrial towns are here at work, side by side; fourthly, we have in this state the important advantage of the possibility of comparing the results of our own studies with the earlier findings, already referred to, of Dr. Derby and Dr. Abbott, the accomplished secretaries of a state board of health highly reputed for its sanitary investigations and its leadership in sanitary subjects. Finally, we have in two states, contiguous to Massachusetts (Connecticut of much the same character as Massachusetts though somewhat less densely populated, and New Hampshire much more sparsely settled than either of the other states) materials for valuable "controls" and comparisons.[1]

As a convenient and suitable statistical unit for our studies we have taken in all three states the New England "town"[2] which is thus defined by the *Century Dictionary:* "In many of the states one of the several subdivisions into which each county is divided, more accurately called, in the New England states and some others, township."

We have already pointed out above that any comparison of urban mortality with rural mortality over large areas is certain, in Massachusetts at least, to be inconclusive, for the reason that all over even the more rural portions of Massachusetts there are scattered spots or small areas to which the term "urban" ought in all fairness to be applied. These may be either old and settled communities which may or may not have supplied themselves with all modern conveniences such as public water-supply and sewerage systems, boards of health, and even garbage and refuse disposal; or they may be factory villages composed chiefly of tenement houses clustered about some busy mill or workshop but as yet destitute of all sanitary appliances and therefore from a sanitary standpoint perhaps actually worse than the neglected alleys of a crowded city. Obviously the blending of the mortality statistics of such spots as these with those of much larger and sparsely settled farming or forest areas into one group to which the term "rural" is arbitrarily applied, and any comparison of the net result with data drawn from places really urban, can give no true idea as to the relative prevalence of disease under strictly rural and urban conditions. What we want is rather a comparison of the mortality of sparsely settled farming or forest areas with the mortality of closely crowded urban districts, and this, fortunately, we can approximately obtain in the New England states, divided as these are into towns (townships) usually of very moderate area and hence often entirely rural. Counties, on the other hand, in New England, as elsewhere, generally comprise much larger areas and include community groups of all sorts among which are often large cities.

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[1] According to the *Census of 1900*, Massachusetts stood second in the Union in order of density of population, with 349 persons per square mile; Connecticut fourth, with 188; and New Hampshire 15th, with 46.

[2] Certain of these are more exactly described as "cities," so that where towns and cities are grouped together we shall often employ the term "communities."

The New England "town" as a community group may, to be sure, be large or small either in area or in population or in both, but as a rule the statements just made hold good and there are in every New England state many small towns which are in every respect strictly rural. Some, on the other hand, have, perhaps in one corner of the town, a little manufacturing settlement gathered about a mill or factory and it is true that:

> "If the town is large the presumption is that it contains a considerable urban population, while if it is small it is probably all or nearly all rural" (*Mass. State Census*, 1905, I, p. xxxi).

The presumption here well set forth becomes a matter of reasonable certainty when the towns are viewed, as we shall view them, in considerable numbers.

For the purposes of our investigations of the mortality statistics of Massachusetts towns, we have used the following methods:

First, we have consulted the state registration reports for the years 1890–1907 inclusive and have computed from the data therein contained the annual death-rates from typhoid fever for the entire 18 years for every town in Massachusetts. The towns have then been arranged in 13 groups, according to their population, and the death-rates of the several *groups* from typhoid fever have also been computed. The results of both procedures are laid down in the following table (p. 163).

On Fig. 1 we have undertaken to show for the communities there grouped three sets of facts: first, by the *base line*, the average aggregate population for each group during the period under consideration; second, upon these base lines we have placed as *verticals* the average typhoid death-rates for the same period. The

TYPHOID FEVER DEATH-RATES (PER 100,000 OF POPULATION) IN MASSACHUSETTS COMMUNITIES GROUPED ACCORDING TO POPULATION. COMPUTED FROM THE MASSACHUSETTS STATE REGISTRATION REPORTS, 1890–1907, INCLUSIVE.

Population Group	Number of Communities	Average Population 1890–1907	Rates by Years																		
			1890*	1891	1892	1893	1894	1895*	1896	1897	1898	1899	1900*	1901	1902	1903	1904	1905*	1906	1907	Average Rate, 18 Years
Less than 500 persons	36	12,300	31	19	54	35	17	38	31	0	31	23	15	0	14	0	24	0	16	0	19.3
500 to 1,000	57	44,600	32	28	17	23	42	33	17	34	25	9	12	5	5	12	10	15	17	2	18.8
1,000 to 1,500	47	57,600	25	28	36	26	21	14	19	19	20	25	17	10	14	12	13	23	14	10	19.3
1,500 to 2,000	38	66,500	30	40	24	20	21	15	30	17	14	17	18	20	6	9	11	14	21	16	19.1
2,000 to 3,000	42	101,400	40	36	33	27	32	23	20	22	24	18	15	11	16	16	11	11	10	10	20.7
3,000 to 4,000	24	79,000	28	29	15	29	20	25	26	9	27	21	18	22	27	14	10	11	11	3	19.3
4,000 to 5,000	22	99,000	26	33	23	23	34	25	29	12	11	6	12	17	15	17	14	15	8	5	18.1
5,000 to 8,000	34	212,000	23	30	47	36	33	27	21	19	19	18	18	18	15	13	11	15	11	5	21.1
8,000 to 10,000	10	90,560	40	32	30	18	25	22	22	20	34	19	18	13	15	10	16	12	20	14	21.2
10,000 to 15,000	16	197,000	29	33	39	32	31	33	27	22	26	22	20	20	20	13	14	19	15	13	23.8
15,000 to 25,000	7	149,900	25	27	28	35	32	36	28	21	25	28	25	18	22	22	20	14	14	19	24.5
25,000 to Worcester (110,000), incl.	20	1,042,000	53	43	43	35	33	25	30	24	22	22	25	20	18	21	15	18	15	16	26.5
Boston	1	528,700	33	33	30	28	28	32	33	31	33	28	25	24	24	20	21	20	20	10	26.3
The state	354	2,680,560	37	36	35	31	31	27	28	23	25	22	22	20	19	18	16	17	16	13	24.3

* Census years. Population for intervening years estimated by method of U.S. Census.

area of the resultant rectangle represents the actual number of deaths in each group annually. In this way we have plotted both the death-rates and the absolute number of deaths from typhoid fever during the period under consideration in Massachusetts communities of various sizes.

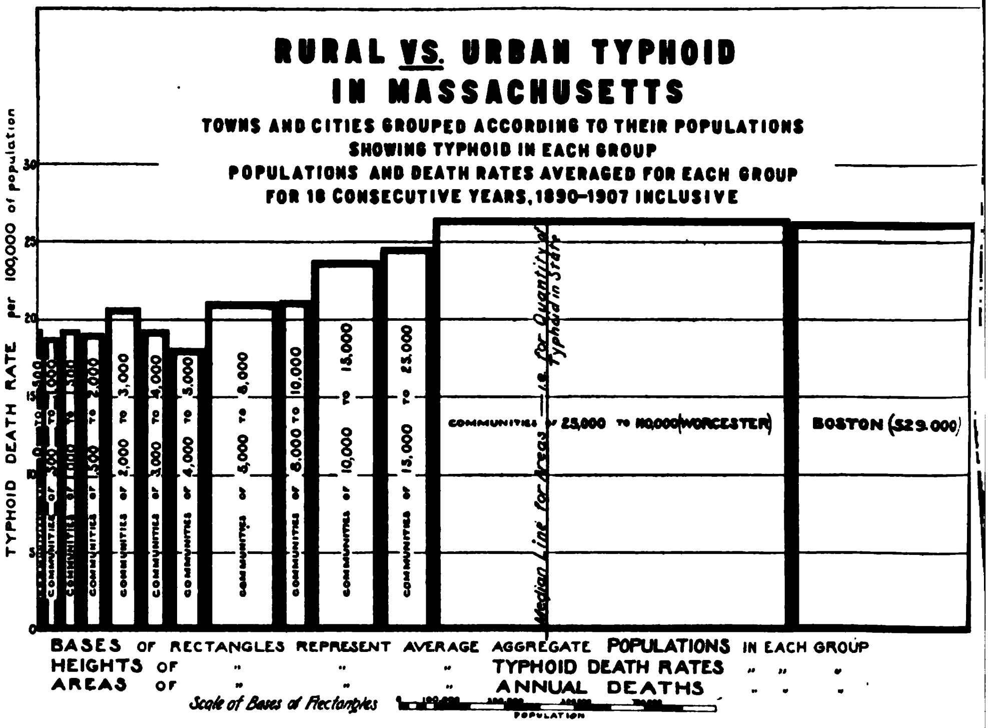

FIG. 1.

It will be observed that the plate shows a fairly regular increase in the death-rates as we proceed from communities of small to those of larger size; and if we consider the areas, that is the absolute quantity or number of deaths, the great balance in favor of the smaller communities and against the larger is very striking. As some further gauge of the distribution of the typhoid deaths, we have indicated in the diagram a line which may be called the *median line* determined by the fact that it divides the total area, that is, the total number of deaths, into two equal parts. In this way a

TYPHOID FEVER MORTALITY IN MASSACHUSETTS COMMUNITIES GROUPED ACCORDING TO POPULATION. DEATH-RATES PER 100,000 OF POPULATION. SIX CENSUS (U.S. OR STATE) YEARS ONLY. COMPILED AND COMPUTED FROM THE STATE REGISTRATION REPORTS.

POPULATION GROUP	1880				1885				1890			
	Number of Communities	Sum of Component Populations	Sum of Typhoid Deaths	Typhoid Death-Rate	Number of Communities	Sum of Component Populations	Sum of Typhoid Deaths	Typhoid Death-Rate	Number of Communities	Sum of Component Populations	Sum of Typhoid Deaths	Typhoid Death-Rate
Less than 500 persons.	22	7,829	3	38	23	7,981	7	88	28	9,772	3	31
500 to 1,000	61	46,474	19	41	72	55,188	19	34	67	52,233	17	33
1,000 to 2,000	92	132,469	66	50	83	122,096	48	39	84	122,798	34	28
2,000 to 3,000	53	127,201	91	72	54	133,250	57	43	48	119,231	45	38
3,000 to 4,000	32	113,509	58	51	29	103,728	41	40	22	75,619	31	41
4,000 to 5,000	28	124,359	77	62	24	106,606	35	33	30	134,154	32	24
5,000 to 6,000	10	54,408	38	70	9	49,816	16	32	7	37,036	7	19
6,000 to 7,000	4	25,530	7	27	8	43,763	22	50	9	57,344	12	21
7,000 to 8,000	6	44,274	15	34	4	29,100	9	31	9	65,825	18	27
8,000 to 9,000	4	33,021	13	39	6	59,547	28	47	5	42,672	14	33
9,000 to 10,000	2	18,338	16	87	5	46,297	9	19	5	47,173	22	47
10,000 to 11,000	5	52,389	16	31	2	21,681	10	46	5	52,462	15	29
11,000 to 12,000	3	34,109	18	53	2	23,266	11	47	2	22,147	2	9
12,000 to 13,000	3	36,618	17	46	3	37,581	17	45	1	12,103	0	0
13,000 to 14,000	3	40,510	22	54	2	26,891	7	26	3	41,251	15	36
14,000 to 15,000	0	......	..	..	2	29,075	5	17	2	29,040	14	48
15,000 to 20,000	3	54,796	15	27	3	51,541	17	33	4	68,785	24	35
20,000 to 25,000	4	89,843	46	51	4	87,955	32	36	4	94,098	17	18
25,000 to 50,000	6	214,134	128	60	8	267,362	111	42	10	344,219	157	46
50,000 to 100,000	3	170,435	63	37	4	249,024	116	47	5	362,504	208	57
100,000 or over	1	362,839	151	42	1	390,393	148	38	1	448,477	146	33
The state........	345	1,783,085	879	49.3	348	1,942,141	765	39.4	351	2,238,943	833	37.2

TYPHOID FEVER MORTALITY IN MASSACHUSETTS COMMUNITIES IN (SIX) CENSUS YEARS—*Continued.*

Population Group	1895				1900				1905			
	Number of Communities	Sum of Component Populations	Sum of Typhoid Deaths	Typhoid Death-Rate	Number of Communities	Sum of Component Populations	Sum of Typhoid Deaths	Typhoid Death-Rate	Number of Communities	Sum of Component Populations	Sum of Typhoid Deaths	Typhoid Death-Rate
Less than 500 persons	36	13,287	5	38	37	13,383	2	15	36	12,513	0	0
500 to 1,000	59	45,804	15	33	53	41,442	5	12	54	40,537	6	15
1,000 to 2,000	86	124,719	18	14	89	129,991	23	18	85	123,870	23	19
2,000 to 3,000	41	100,555	23	23	37	88,785	14	16	43	100,993	11	11
3,000 to 4,000	23	76,902	19	25	27	93,751	17	18	18	62,709	7	11
4,000 to 5,000	23	104,395	25	24	17	76,412	9	12	20	88,249	13	15
5,000 to 6,000	15	80,171	16	20	19	102,514	20	20	15	81,638	14	17
6,000 to 7,000	11	69,668	19	27	7	44,836	8	18	13	84,643	13	15
7,000 to 8,000	10	76,315	26	34	11	81,609	14	17	10	73,437	9	12
8,000 to 9,000	6	50,796	13	26	4	34,212	3	9	5	42,453	5	12
9,000 to 10,000	4	37,891	7	18	5	47,549	15	32	4	37,496	5	13
10,000 to 11,000	2	21,170	10	47	3	31,233	1	32	2	20,286	3	15
11,000 to 12,000	5	58,385	16	27	6	67,994	19	28	5	56,510	9	16
12,000 to 13,000	0	......	..	..	3	37,664	5	13	5	61,964	13	21
13,000 to 14,000	0	......	..	..	4	54,404	5	9	3	39,814	10	25
14,000 to 15,000	4	58,181	20	34	2	28,732	10	35	6	86,252	16	19
15,000 to 20,000	5	87,038	37	43	4	75,989	19	25	3	54,866	13	24
20,000 to 25,000	3	62,049	17	27	5	117,682	27	23	3	65,777	4	6
25,000 to 50,000	10	308,466	68	22	10	348,917	92	26	14	483,807	94	19
50,000 to 100,000	9	627,471	166	26	7	504,071	120	24	7	556,589	94	17
100,000 or over	1	496,920	160	32	3	784,176	204	26	3	829,277	157	19
The state	353	2,500,183	680	27.2	353	2,805,346	632	22.5	354	3,003,680	519	17.3

certain size of community is found such that the two groups of communities of small size and larger size, respectively, have the same absolute number of deaths. The median line, therefore, indicates where the actual deaths would exert their center of gravity, so to speak; and for Massachusetts, as shown upon Fig. 1, this median line falls in the left-hand part of the "25,000 to Worcester (incl.)" group. Similar subdivision into smaller groups would show exactly at what size of community the median line falls, but the example just given is sufficient for our purpose. Tried by this test, the bulk of the deaths certainly does not rest upon the more rural towns but rather upon the least rural namely, the largest cities. From this demonstration, therefore, we arrive at our first conclusion, which is that *typhoid fever is not chiefly a rural but rather an urban disease.* Obviously, however, this conclusion applies only to what we may call the mass of typhoid, or of typhoid fever microbes or of typhoid fever material, which would naturally be expected if gathered together to be greater in large than in small populations.

Next, in order to eliminate inaccuracies due to estimates of populations for non-censal years, and to carry our group analysis further, we have studied for six Census years 1880, 1885, 1890, 1895, 1900, and 1905 the typhoid fever mortality of the various communities of Massachusetts arranged according to their population into 21 groups. The rate columns in the above table were calculated by computing for each Census year the typhoid fever death-rate for every town in Massachusetts, each town being assigned to the group into which it fell for the particular Census year. The table shows the results of these computations.

We have then averaged the first two Census years against the last four. The results are shown in the following table (p. 168).

The figures given in this last table are plotted for easy reference and futher study upon Fig. 2, in which the method of presentation corresponds with that used in Fig. 1 and in which the same scales are employed for both upper and lower diagram, and Fig. 2, taken together with the table, demonstrates some of the most striking results of our investigation, namely, as follows:

1. In the first place it appears that the total population of the

state increased between the earlier and the later years about 40 per cent. This increase was chiefly among the cities having more than 25,000 population, although it was shared by many communities ranging from 5,000 upward. On the other hand, population in towns having less than 5,000 actually decreased by some 15 per cent. This movement of the population must be carefully kept in mind wherever conclusions are to be drawn.

TYPHOID FEVER DEATH-RATES (PER 100,000 OF POPULATION) IN MASSACHUSETTS COMMUNITIES GROUPED ACCORDING TO POPULATION (CENSUS YEARS).

COMMUNITIES HAVING POPULATIONS OF	AVERAGES FOR 1880 AND 1885		AVERAGES FOR 1890, 1895, 1900, AND 1905	
	Population	Typhoid Death-Rate	Population	Typhoid Death-Rate
Less than 500	7,900	63	12,240	21
500 to 1,000	50,830	38	45,000	23
1,000 to 2,000	127,290	45	125,340	20
2,000 to 3,000	130,230	58	102,390	22
3,000 to 4,000	108,620	46	77,250	24
4,000 to 5,000	115,490	48	100,800	19
5,000 to 6,000	52,110	51	75,340	19
6,000 to 7,000	34,650	39	64,120	20
7,000 to 8,000	36,690	33	74,300	22.5
8,000 to 9,000	46,280	43	42,530	20
9,000 to 10,000	32,320	53	42,530	27.5
10,000 to 11,000	37,030	39	31,290	31
11,000 to 12,000	28,690	50	51,260	20
12,000 to 13,000	37,100	46	27,930	11
13,000 to 14,000	33,700	40	33,870	23
14,000 to 15,000	14,540	17	50,550	34
15,000 to 20,000	53,170	30	71,670	32
20,000 to 25,000	88,900	44	84,900	18.5
25,000 to 50,000	240,750	51	371,350	28
50,000 to 100,000	209,730	42	512,660	31
100,000 to 130,000	....	..	114,300	27.5
Boston	376,620	40	525,420	27.5
State of Massachusetts	1,862,610	44.35	2,637,040	26.05

2. Inasmuch as the deaths were, on the whole, somewhat less for the various communities during the later years (owing, no doubt, to general sanitary improvements) and while, as we have just said, the population increased during the same period, the typhoid fever death-rates, as indicated by the diagram, declined for the most part conspicuously, between the earlier and the later years.[1]

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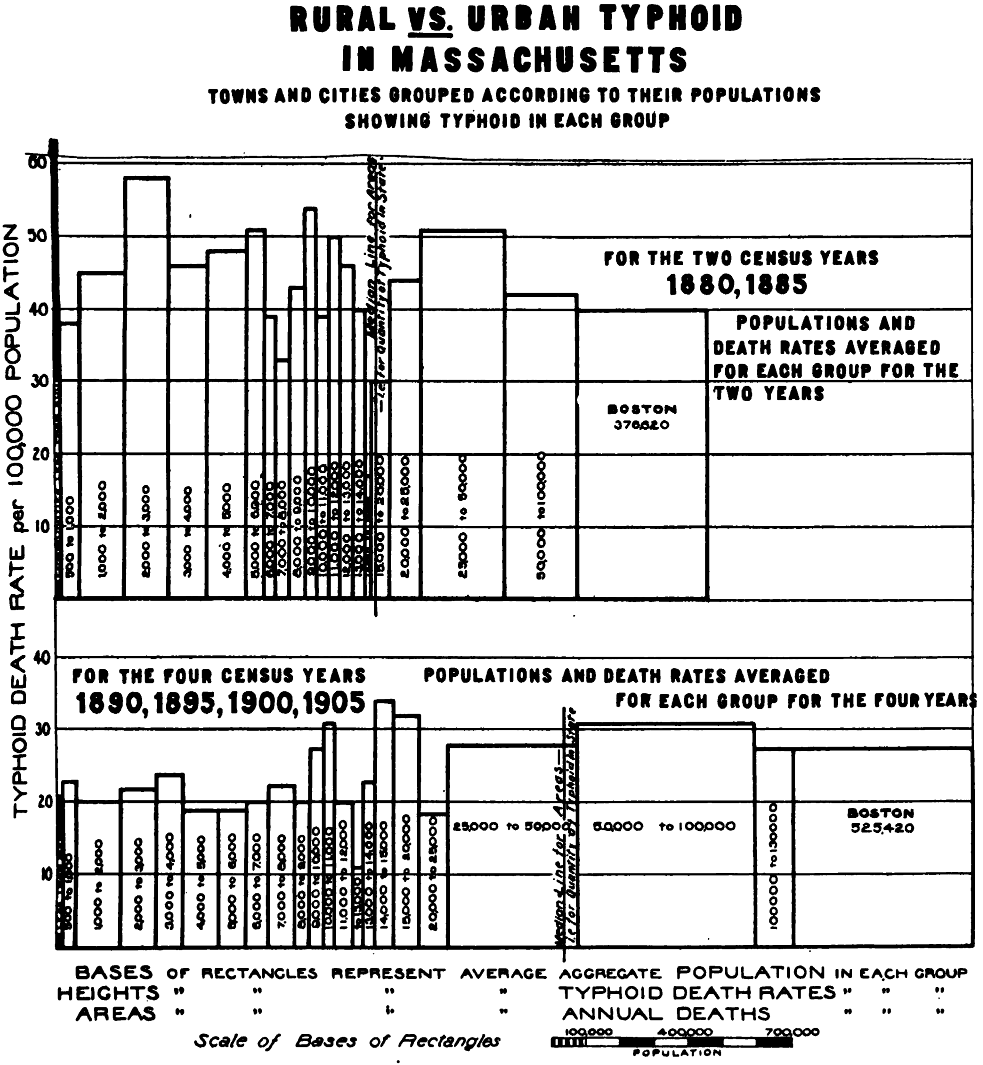
[1] The question may be raised at this point as to how far this decline in death-rates is attributable to improved methods of diagnosis. It is of course true that with the establishment and growth of hospitals and the general improvement of facilities for medical observation and investigation, accuracy in the diagnosis of typhoid fever has been much increased since 1880. We are not at present, however, especially concerned with the reasons underlying the general decline in death-rates, and we see no reason for suspecting that any quantitative relation of rural and urban typhoid has been much obscured by changes in methods of diagnosis, or that improved diagnosis could have brought about any merely apparent reversal in that relation between 1880 and 1907. We shall return to this subject in a later section.



RURAL VS. URBAN TYPHOID IN MASSACHUSETTS

TOWNS AND CITIES GROUPED ACCORDING TO THEIR POPULATIONS SHOWING TYPHOID IN EACH GROUP

FIG. 2.

3. The decline in the amount of typhoid fever as indicated by the decline in death-rates from that disease was considerably greater among the smaller than among the larger communities. This decline is especially noteworthy in the groups having less than 6,000 population.

4. The median line for areas (i.e., for the number of deaths) falls for 1880 and 1885 in the vicinity of populations of 15,000, and for the later years has moved toward a much larger community-size, namely, about 50,000 population.

5. The most important result disclosed by the diagram for our purposes is, however, that in the earlier period the groups of smaller communities showed the highest typhoid fever death-rates, while in the later years this relation is reversed.

The results here obtained are in close accordance with the findings, referred to above, of Dr. S. W. Abbott, who confirmed the earlier study of Dr. Derby, and attributed to the smaller communities previous to 1891 a relatively greater prevalence of typhoid fever. It appears, however, that (as is stated in the last paragraph) an exact reversal of this relation appears to have taken place since the period covered by Dr. Abbott's study, namely, 1871–90. It becomes an interesting question what precisely has led to this singular reversal, which apparently compels us to conclude that whereas before 1890 typhoid fever was in fact a rural disease, since that time it has gradually become an urban disease—a curious circumstance, and one which, if confirmed, justifies both the conclusions of earlier authorities like Drs. Derby and Abbott, and also the suspicion and incredulity which impelled us to undertake the present investigation. To a further consideration of this point we shall return hereafter.

Finally, in order to carry into still greater detail the studies described above and to establish a basis of comparison for the present time with the interesting studies of individual towns made by Drs. Derby and Abbott, we have calculated for the period of 18 years already under consideration, beginning with 1890, the average annual death-rate from typhoid fever for the various communities of the state of Massachusetts. These have then been arranged in the order of their typhoid fever death-rates in the following table:

AVERAGE ANNUAL TYPHOID FEVER DEATH-RATES PER 100,000 OF POPULATION MASSACHUSETTS COMMUNITIES, 1890–1907, INCLUSIVE.

Community	Average Population 1890–1907	Typhoid Death-Rate
TOWNS WITH NO DEATHS		
Gosnold	150	0
Alford	281	0
Boxborough	318	0
Prescott	370	0
Shutesbury	413	0
Plainfield	418	0
Westhampton	472	0
Wendell	501	0
Halifax	519	0
Rowe	530	0
Plympton	537	0
Windsor	549	0
Oakham	612	0
Richmond	694	0
Princeton	954	0
Millis	1,024	0
Wellfleet	1,051	0
Sandwich	1,570	0
Total population	10,963	
Plainville (1905–7 only. Incorporated 1904)	1,300	0
Westwood (1900–1907 only. Incorporated 1899)	1,124	0
TOWNS WITH RATE 0–5		
Nantucket	3,031	1.8
Rehoboth	1,857	3.0
Freetown	1,421	4.0
Pembroke	1,261	4.2
Bedford	1,169	4.4
Total population	8,739	
TOWNS WITH RATE 5–10		
Ashfield	988	5.4
Stow	963	5.5
Southwick	991	5.6
Gill	1,020	5.8
Truro	811	6.2
Shrewsbury	1,616	6.7
Lynnfield	822	6.8
Ashby	842	6.9
Holbrook	2,377	6.9
Wellesley	4,938	7.0
Brookline	18,679	7.2
Marion	890	7.3
Granby	780	7.3
Falmouth	3,032	7.7
Hopkinton	2,957	8.0
Georgetown	1,960	8.5
Rutland	1,251	8.6
Walpole	3,379	8.7
Orleans	1,148	9.2
Burlington	593	9.5
West Bridgewater	1,845	9.6
Marshfield	1,761	9.6
New Braintree	523	9.7
Sudbury	1,162	9.7
Easthampton	5,551	9.9
Whitman	5,868	9.9
Lincoln	837	9.9
Harvard	1,118	9.9
Bourne	1,616	9.9
Total population	70,318	
TOWNS AND CITIES WITH RATE 10–15		
Holliston	2,649	10.4
Groton	2,138	10.5
Southboro	2,047	10.5
Warwick	577	10.6
Canton	4,625	10.8
Raynham	1,515	10.9
Manchester	2,201	10.9
Lexington	3,849	10.9
Savoy	530	11.0
Enfield	988	11.1
Southampton	1,102	11.1
Westminster	1,425	11.1
Newbury	1,499	11.1
Ashland	1,936	11.1
Hanover	2,119	11.1
Hingham	4,843	11.5
Heath	444	11.7
Conway	1,388	11.7
East Longmeadow	1,368	11.9
Shirley	1,465	11.9
Easton	4,695	12.0
Lancaster	2,316	12.1
Monterey	464	12.2
Mendon	910	12.2
Ayer	2,270	12.2
Paxton	443	12.3
Seekonk	1,593	12.4
Avon	1,663	12.4
Hatfield	1,672	12.4
Hawley	465	12.5
Chatham	1,786	12.5
North Brookfield	3,935	13.0
Milton	6,048	13.0
Yarmouth	1,622	13.1
Florida	419	13.3
Monson	3,827	13.5
Medway	2,827	13.6
Littleton	1,390	13.7
Brewster	849	13.7
Dedham	7,432	13.7
Whately	781	13.8
Bridgewater	5,518	13.9
Bernardston	777	14.0
Hampden	729	14.1
Bolton	789	14.2
Hull	1,449	14.2
Hamilton	1,394	14.3
Belmont	3,453	14.3
Franklin	5,091	14.3
Shelburne	1,529	14.5
Northfield	1,933	14.5
Mansfield	3,906	14.5
Ware	8,044	14.5
Merrimac	2,237	14.6
Barnstable	4,219	14.6
Medfield	2,509	14.7
Marlboro	14,165	14.7

AVERAGE ANNUAL TYPHOID FEVER DEATH-RATES PER 100,000 OF POPULATION, MASSACHUSETTS COMMUNITIES, 1890–1907, INCLUSIVE—*Continued.*

Community	Average Population 1890–1907	Typhoid Death-Rate
Boxford	740	14.8
Mattapoisett	1,105	14.8
Gloucester	26,428	14.9
Fitchburg	28,886	14.9
Total population	201,016	
TOWNS AND CITIES WITH RATE 15–20		
Millbury	4,719	15.0
Winchester	6,854	15.0
Dana	742	15.1
Kingston	1,891	15.1
Stoneham	6,256	15.1
Leominster	11,077	15.1
Sheffield	1,859	15.2
Stoughton	5,457	15.4
Spencer	7,670	15.6
Tyngsboro	709	15.7
Hadley	1,764	15.7
Wayland	2,152	15.8
Winthrop	5,292	15.8
Topsfield	1,045	15.9
Wareham	3,487	16.0
Swampscott	4,149	16.2
South Hadley	4,623	16.2
Saugus	5,109	16.2
Concord	5,251	16.3
Middleboro	6,695	16.3
Peabody	11,501	16.3
West Newbury	1,600	16.4
Rockport	4,673	16.5
Newton	31,375	16.5
Hardwick	3,022	16.7
Revere	9,485	16.7
Swanzea	1,642	16.8
Peru	283	17.0
Sterling	1,299	17.0
Essex	1,688	17.0
Duxbury	1,994	17.0
Pepperell	3,381	17.0
East Bridgewater	3,014	17.0
Montague	6,412	17.0
Amherst	4,963	17.2
Andover	6,465	17.2
Foxboro	3,217	17.3
Fairhaven	3,709	17.3
Danvers	8,422	17.5
Auburn	1,689	17.6
Arlington	7,849	17.6
Goshen	298	17.7
Brimfield	974	17.8
Bellingham	1,547	17.8
Westboro	5,381	17.8
Melrose	12,291	17.8
West Boylston	2,404	18.0
Deerfield	2,458	18.0
Templeton	3,338	18.0
Barre	2,283	18.1
Medford	16,450	18.1
Buckland	1,516	18.2
Reading	4,977	18.2
Mashpee	312	18.3
Norfolk	963	18.3
Middleton	917	18.5
Berlin	922	18.5
Cambridge	87,650	18.5
Worcester	110,400	18.5
North Andover	4,087	18.7
Monroe	288	18.8
Wenham	886	18.8
North Reading	912	18.9
Eastham	525	19.0
West Brookfield	1,473	19.0
Chesterfield	593	19.1
Weston	1,851	19.1
Northboro	2,001	19.2
Upton	1,997	19.3
Watertown	9,215	19.3
Framingham	10,537	19.6
Sherborn	1,422	19.7
Hinsdale	1,581	19.7
Longmeadow	1,144	19.8
Brookfield	2,983	19.9
Westford	2,426	19.9
Hyde Park	12,723	19.9
Total population	505,505	
TOWNS AND CITIES WITH RATE 20–25		
Cohasset	2,602	20.0
Egremont	790	20.1
Abington	4,557	20.2
Montgomery	268	20.3
North Attleboro	7,164	20.4
Sunderland	760	20.5
Braintree	5,885	20.7
Plymouth	9,180	20.7
Lynn	67,336	20.7
Southbridge	9,439	20.8
Everett	22,011	20.8
Warren	4,432	20.9
West Springfield	6,805	20.9
Athol	7,062	21.0
Billerica	2,644	21.1
Wakefield	8,935	21.1
Charlemont	1,027	21.2
Dartmouth	3,460	21.2
Norwell	1,567	21.3
Hubbardston	1,263	21.4
Stockbridge	2,078	21.6
Chelmsford	3,624	21.6
Somerville	57,790	21.6
Sharon	1,874	21.7
Taunton	29,061	21.7
Malden	32,050	21.7
Dudley	3,436	21.8
Great Barrington	5,335	21.8
Palmer	7,315	21.8
Brockton	38,424	21.8
Ashburnham	1,900	21.9
Northampton	17,915	22.0
Acton	2,016	22.1
Leicester	3,317	22.1
Clarksburg	1,009	22.2
Greenfield	7,391	22.2
Chelsea	33,260	22.3
Carlisle	494	22.4
Erving	1,001	22.4
Lunenburg	1,252	22.4
Gardner	10,335	22.5
Woburn	14,151	22.6
Rockland	5,661	22.8
Hancock	475	22.9
Lenox	2,948	22.9

AVERAGE ANNUAL TYPHOID FEVER DEATH-RATES PER 100,000 OF POPULATION, MASSACHUSETTS COMMUNITIES, 1890–1907, INCLUSIVE—*Continued.*

Community	Average Population 1890–1907	Typhoid Death-Rate
Oxford	2,652	23.0
Marblehead	7,606	23.0
Charlton	1,927	23.1
Orange	5,335	23.1
Quincy	23,101	23.1
Norwood	5,098	23.2
Beverly	13,211	23.2
Huntington	1,440	23.3
Tewksbury	3,631	23.3
Wilmington	1,475	23.4
Attleboro	10,293	23.4
Petersham	927	23.6
Berkeley	932	23.6
Nahant	963	23.6
Holden	2,582	23.6
Weymouth	11,319	23.7
Clinton	12,312	23.7
Waltham	24,832	24.0
Westport	2,759	24.3
Lakeville	919	24.4
Natick	9,516	24.6
Dover	672	24.8
Total population	594,800	
TOWNS AND CITIES WITH RATE 25–30		
Townsend	1,776	25.0
Holyoke	43,850	25.6
Washington	388	25.8
Oak Bluffs	1,089	25.8
New Marlboro	1,271	25.8
Winchendon	5,045	26.0
Hudson	5,523	26.2
Colrain	1,702	26.3
Boston	535,417	26.3
Pittsfield	21,633	26.3
Dunstable	414	26.5
Grafton	5,012	26.6
Milford	10,498	26.7
Maynard	3,851	27.0
Ipswich	4,808	27.0
Haverhill	35,774	27.0
Fall River	95,715	27.2
Webster	7,606	27.4
Middlefield	412	27.5
Holland	230	27.8
Boylston	878	27.9
Norton	1,826	27.9
Uxbridge	3,639	27.9
Williamsburg	1,961	28.0
Dighton	1,889	28.1
Somerset	2,156	28.1
Williamstown	4,682	28.2
Randolph	3,913	28.3
Amesbury	9,494	28.5
Westfield	11,840	28.5
Needham	3,712	28.7
Methuen	6,918	28.7
New Bedford	60,523	28.7
Edgartown	1,166	28.8
Chester	1,374	28.8
Salem	35,204	28.8
Rowley	1,325	29.2
Dracut	2,857	29.2
West Tisbury	453	29.3
Wales	725	29.3
Cummington	758	29.5
Tyringham	368	29.7
Agawam	2,273	29.8
Total population	941,948	
TOWNS AND CITIES WITH RATE 30–40		
Tisbury	1,194	30.1
Northbridge	6,257	30.2
Dennis	2,494	30.7
Salisbury	1,474	30.8
Sturbridge	2,004	31.0
Wrentham	2,324	31.2
Gay Head	165	31.4
Dalton	3,080	31.4
Russell	893	31.9
Wilbraham	1,724	32.1
Otis	528	32.4
Lee	3,865	32.7
Groveland	2,330	33.0
Provincetown	4,433	33.3
Acushnet	1,162	33.6
Chilmark	326	34.8
Phillipston	461	34.9
Pelham	473	34.9
Scituate	2,408	35.0
Royalston	945	35.3
Cheshire	1,246	35.5
Rochester	1,050	36.3
Chicopee	17,869	36.5
Belchertown	2,165	36.9
Hopedale	1,672	37.5
Newburyport	14,471	37.7
Harwich	2,473	38.1
Tolland	313	38.2
Douglas	2,042	38.2
New Salem	601	38.5
Sutton	3,230	38.9
Total population	85,672	
TOWNS AND CITIES WITH RATE 40–50		
Greenwich	493	40.7
Ludlow	3,050	41.7
West Stockbridge	1,232	42.0
Lawrence	59,018	43.4
Granville	995	43.4
Hanson	1,398	43.4
Lanesboro	873	43.6
Lowell	89,100	43.7
North Adams	20,871	46.2
Blandford	825	48.5
Becket	929	48.5
Total population	178,784	
TOWNS WITH RATE OVER 50		
Carver	1,131	50.4
Blackstone	5,904	52.9
Adams	10,317	53.3
Leyden	388	57.6
Sandisfield	732	63.2
Mt. Washington	123	77.4
Leverett	723	84.2
New Ashford	112	90.4
Total population	19,430	

Populations based on U.S. Census for 1890 and 1900, and State Census for 1895 and 1905. Deaths from State Registration Reports.

From these detailed tables another, and general one, may be made enabling us to compare at a glance the typhoid fever death-rates of communities of various sizes (or population) for the 18 years under consideration as follows:

MASSACHUSETTS COMMUNITIES ARRANGED BY POPULATION GROUPS AND TYPHOID FEVER DEATH-RATES (PER 100,000) FOR THE YEARS 1890–1907, INCLUSIVE.

TYPHOID DEATH-RATE AT OR BETWEEN	AVERAGE POPULATION OF COMMUNITIES, 1890–1907							
	Under 1,000	1,000–2,000	2,000–3,000	3,000–5,000	5,000–10,000	10,000–25,000	25,000–125,000	Over 125,000
0	7,318	3,645	0	0	0	0	0	0
0– 5	0	4,708	0	3,031	0	0	0	0
5–10	9,040	14,497	5,334	11,349	11,419	18,679	0	0
10–15	9,905	28,834	23,313	37,352	32,133	14,165	55,314	0
15–20	9,324	29,002	16,707	55,359	101,813	74,579	229,425	0
20–25	7,200	15,735	20,280	26,457	107,727	159,480	257,921	0
25–30	4,626	15,379	7,286	24,605	39,598	43,971	271,066	535,417
30–40	4,705	9,522	18,240	14,608	6,257	32,340	0	0
40–50	4,115	2,630	0	3,050	0	20,871	141,118	0
Over 50	2,078	1,131	0	0	5,904	10,317	0	0
Totals	58,311	125,083	91,160	175,811	304,851	374,402	961,844	535,417

The data shown upon the foregoing basic or detailed tables are presented graphically upon Fig. 3, where the typhoid fever death-rates of the various communities of Massachusetts as arranged in the tables have been plotted diagrammatically in the same order of succession. The vertical bars represent by their height the population of each community, and in the case of some of the largest towns and cities these bars have had to be broken off in order to bring them within the limits of the diagram. Whenever this has been done the bar has been broken in the middle, the upper half omitted, and the actual population indicated upon the remaining lower half. The authors are personally familiar with many of the towns and cities of Massachusetts, but it would be impossible without unduly lengthening the present paper to take up for consideration the individual communities. We shall therefore merely point out some of the more salient features developed by the diagram.

The observer cannot fail to be struck by the absence from the upper line of the series (which represents communities having the lowest typhoid fever death-rates) of communities of the larger or even medium size. On the contrary, many of the very smallest here find a place, and, with the single exception of Brookline, there is no community among the first 110 of the series which has a population of more than 8,000—the dividing line, it will be remembered, of the U.S. Census of 1900 between rural and urban communities—while the majority (61) of these, are well under 1,500 population. It is certainly a significant fact that of 20 towns which had no deaths whatever from typhoid fever during the 18 years under consideration, only one had more than 1,500 population.

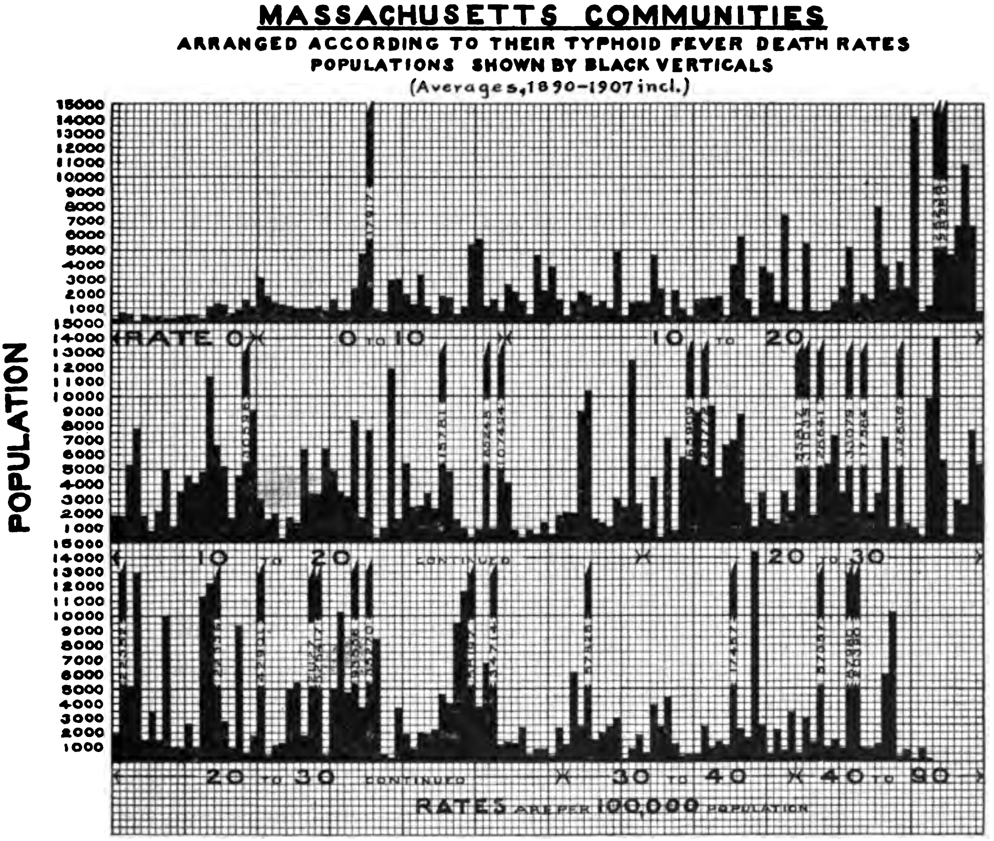


FIG. 3.

Passing from the lower death-rates to the higher, towns of medium size and large size become more frequent, although there are scattered among these all the way along a few of the more strictly rural communities. When we reach the groups having death-rates of 20–30, the number of communities having 15,000 population and upward is remarkable. Rates 30–40 and 40–90 are represented by comparatively few communities of any kind and those of various sizes.

Going more into details we find from rate 0 to rate 10 per 100,000 only one community in 54 with as many as 6,000 population, most of the other 53 falling below 2,000. Low populations continue to be associated with low death-rates well into the next (rate 10 to 20) group but as we advance toward rate 20 per 100,000 a large number of comparatively urban communities appear. These are still more conspicuous as we pass into the region of rate 20 to 30, but become less frequent as we pass the rate 30 line. Beyond this line low populations with high typhoid death-rates are again more abundant, although out of the 51 communities having death-rates of 30 or more per 100,000, nine have 6,000 or more population. Again, out of the 55 communities having the lowest death-rates from typhoid fever 54 had less than 6,000 population, while out of the 51 having the highest death-rate only 42 had less than 6,000.

As to the total population in the rate 0 to rate 10 group we find that this is about 90,000, while that in the group between rate 30 and rate 90 is very much larger. The former is distinctly a rural group; the latter much more urban. In view of this presentation of the subject it is hard to believe that typhoid fever today is, in any true sense of the term, "a rural disease."

We may now bring together the most obvious results of our studies above described upon the prevalence of typhoid fever in Massachusetts communities of various sizes:

Among the twelve groups taken for study for the entire period, 1890–1907, typhoid fever is not found to be either absolutely or relatively to the population a "rural" disease. On the contrary, during this period, typhoid fever has prevailed somewhat more among larger than among smaller communities.

Our second analysis (of 21 groups confined to Census years) confirms this result and in addition brings out the fact that this was not the case prior to 1890, thus confirming the earlier findings and opinions of Drs. Derby and Abbott and also probably explaining the origin of the belief of today that typhoid fever is a rural disease.

The results of a detailed study of the more than 350 communities into which Massachusetts is divided, confirms and strengthens the foregoing conclusions, by showing that a large number of the smallest and most rural communities are among those having the lowest typhoid fever death-rates, as well as a scarcity among the latter of communities of large size; and, on the other hand, revealing a notable concentration of relatively large communities in the groups having comparatively high death-rates.

We are evidently driven by all our considerations to the conclusion that no matter whether we take as a basis the total amount of typhoid fever material existing in the various communities of the state, or the specific death-rates from that disease, typhoid fever in Massachusetts since 1890 cannot possibly be regarded as "a rural disease." It appears, on the contrary both from our tables and our diagrams, not only that there is very much more typhoid fever in the city than there is in the country, but also that there is more of it there in proportion to the population. Typhoid fever must for the present, therefore, be regarded as an urban rather than a rural disease, at least in Massachusetts.

5. EVIDENCE DERIVED FROM THE VITAL STATISTICS OF THE STATE OF CONNECTICUT.

For comparison with Massachusetts we have next taken Connecticut, a state very similar in general and industrial character of population. The relative distribution of population between communities of smaller and larger sizes is somewhat but not very different in the two states, and here, as in Massachusetts, we have taken the "town" as our statistical community unit. We are fortunate also in having again the reliable vital statistics of a registration state upon which to make our researches.

Corresponding with what we have already done for Massachusetts, we have computed the following death-rates for certain groups of towns in Connecticut:

TYPHOID FEVER DEATH-RATES (PER 100,000 OF POPULATION) IN CONNECTICUT COMMUNITIES GROUPED ACCORDING TO POPULATION· COMPUTED FROM THE CONNECTICUT STATE REGISTRATION REPORTS (1890–1907, INCLUSIVE).

Population Group	Number of Communities	Average Population 1890–1907	Rates by Years																		Average Rate 18 Years
			1890*	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900*	1901	1902	1903	1904	1905	1906	1907	
Less than 500 persons	7	3,040	0	13	31	94	0	32	0	0	0	0	0	0	34	0	0	0	0	0	11.4
500 to 1,000	37	27,100	42	35	21	43	50	25	15	15	7	19	19	11	15	11	19	19	20	16	22.4
1,000 to 1,500	24	31,200	34	51	35	40	28	16	25	19	20	23	24	14	16	13	10	9	12	12	22.4
1,500 to 2,000	18	28,500	50	33	34	27	33	20	11	4	14	9	26	13	14	4	14	21	12	12	19.5
2,000 to 3,000	24	57,100	19	36	27	37	30	21	14	11	15	14	37	15	13	8	13	14	24	20	20.4
3,000 to 4,000	17	65,300	34	29	29	27	49	31	22	11	16	15	21	15	7	7	5	12	12	10	19.6
4,000 to 5,000	7	32,000	54	53	53	40	34	26	19	10	16	22	19	13	25	15	25	28	13	11	26.4
5,000 to 8,000	12	77,800	30	47	39	36	35	23	31	25	10	31	34	14	29	8	15	18	15	24	25.7
8,000 to 10,000	4	35,800	12	52	86	31	29	27	22	15	15	17	62	16	7	20	30	23	20	11	27.5
10,000 to 15,000	6	61,200	47	40	50	26	12	37	22	7	22	21	32	12	15	9	19	25	12	17	23.6
15,000 to 25,000	6	117,600	57	39	36	38	26	46	23	15	16	12	25	25	32	34	13	23	19	33	28.4
25,000 to Bridgeport (67,700)	4	169,600	55	34	36	28	19	20	24	20	22	16	26	25	25	22	17	17	17	20	24.6
Hartford (75,900) and New Haven (104,700)	2	180,600	39	40	48	36	38	42	34	26	40	34	38	74	29	30	21	32	44	25	37.2
State	168	886,840	42	39	40	35	31	31	24	18	22	21	31	30	22	22	17	22	22	20	27.1

* Census years. Population for intervening years estimated by method of U.S. Census.

From the above table we have plotted Fig. 4, in which the method of presentation is the same as that employed in Fig. 1. We must, however, caution the reader that in order to reduce this diagram (as well as the following diagram of New Hampshire data) to the limits of the page, we have used a different base-line scale, and for the same reason, a different vertical scale for death-rates. Hence exact graphical comparisons from one figure to another of this series cannot be made.

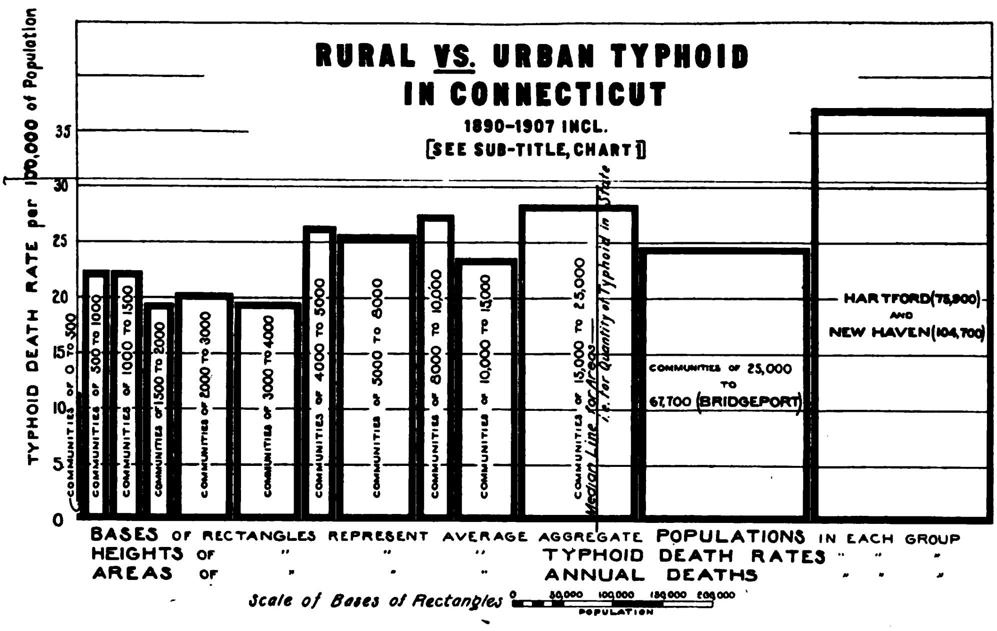


Fig. 4.

Surveying the Connecticut groups, we note the similarity of the distribution of typhoid fever here—whether measured by rates or by total deaths—with that in Massachusetts. The groups of communities of 1,500 to 2,000 and of 3,000 to 4,000 population show the minimum rates of about 19, and from that level the rates range to the group of the largest communities, embracing Hartford and New Haven, which group shows a rate of more than 37. In general also there is a progressive increase of rates from the smallest to the largest communities. If the total deaths, as indicated by the areas of the rectangles, be taken into account, we find that the bulk of the deaths among communities of over 15,000 population much exceeds that among all the smaller, the median point for the areas (=deaths) falling between 15,000 and 25,000. The total deaths among the smallest communities—say under 3,000—is seen to be but a small proportion of the whole quantity of typhoid mortality.

For Connecticut we have also compiled the average annual death-rates from typhoid fever for each town and city for the 18 years under consideration and the results grouped in the order of such death-rates, from rate zero to rate 50 or more, are shown in detail in the following table:

AVERAGE ANNUAL TYPHOID FEVER DEATH-RATES PER 100,000 OF POPULATION IN CONNECTICUT COMMUNITIES, 1890–1907, INCLUSIVE. COMPILED FROM THE STATE REGISTRATION REPORTS.

Community	Average Population 1890–1907	Average Typhoid Fever Rate 1890–1907
TOWNS WITH NO DEATHS		
Beacon Falls	465	0
Hartland	588	0
Lyme	784	0
Marlboro	361	0
Salem	465	0
Total population	2,663	
TOWNS WITH RATE 0–5		
Preston	2,764	2.2
Stratford	3,450	3.7
Total population	6,214	
TOWNS WITH RATE 5–10		
Monroe	1,036	5.4
Sharon	2,007	5.6
Coventry	1,668	6.4
Willington	889	6.4
Wilton	1,616	6.6
East Haddam	2,502	6.6
Weston	830	6.8
Canton	2,651	8.3
Newtown	3,316	8.4
Lebanon	1,543	8.7
Fairfield	4,395	8.6
Harwinton	1,170	9.9
Total population	23,623	
TOWNS AND CITIES WITH RATE 10–15		
Pomfret	1,777	10.4
Wolcott	573	10.4
East Haven	1,134	10.5
Bethany	522	10.8
Barkhamstead	900	10.8
Easton	967	11.5
Middlefield	868	11.6
Windsor Locks	3,015	11.7
Colchester	2,141	11.9
Essex	2,473	11.9
Bolton	456	12.1
Warren	439	12.2
Goshen	855	12.3
Chester	1,325	12.6
Canterbury	888	12.6
East Windsor	3,118	12.6
Salisbury	3,480	12.8
Union	428	12.9
Plainville	2,159	12.9
Suffield	3,467	12.9
Old Lyme	1,201	13.0
Granby	1,292	13.0
North Branford	817	13.6
Litchfield	3,228	13.8
Darien	2,993	13.9
Norfolk	1,603	13.9
Bridgeport	67,676	14.6
Griswold	3,434	14.7
Saybrook	1,611	14.7
Cheshire	1,960	14.9
Total population	116,820	
TOWNS AND CITIES WITH RATE 15–20		
South Windsor	1,972	15.0
Plainfield	4,785	15.0
Wethersfield	2,582	15.3
Ellington	1,785	15.6
Newington	1,028	15.8
Rocky Hill	1,032	15.9
Guilford	2,784	16.0
Milford	3,787	16.2
Columbia	668	16.6
Middlebury	710	16.7
North Stonington	1,278	17.2
New Milford	4,669	17.4

AVERAGE ANNUAL TYPHOID FEVER DEATH-RATES PER 100,000 OF POPULATION IN CONNECTICUT COMMUNITIES, 1890–1907, INCLUSIVE. COMPILED FROM THE STATE REGISTRATION REPORTS—*Continued.*

Community	Average Population 1890–1907	Average Annual Rate 1890–1907
Norwich	24,400	17.4
Torrington	11,492	17.5
Seymour	3,504	17.5
Bridgewater	644	17.7
Trumbull	1,567	17.8
Colebrook	746	17.9
Berlin	3,321	17.9
Groton	5,898	17.9
Burlington	1,232	18.2
Canaan	843	18.2
Southbury	1,216	18.3
Westbrook	882	18.3
Avon	1,284	18.3
Montville	2,387	18.7
Vernon	8,531	18.8
Woodbridge	864	19.2
Meriden	28,176	19.4
North Haven	2,119	19.9
Total population	126,196	
TOWNS WITH RATE 20–25		
Franklin	551	20.2
Greenwich	11,865	20.2
Prospect	535	20.3
Morris	542	20.3
Woodbury	1,961	20.4
Winchester	7,526	20.7
Sprague	1,304	20.9
Chatham	2,212	21.0
Chaplin	532	21.1
Portland	4,009	21.1
Mansfield	1,839	21.1
New Canaan	2,934	21.1
Thompson	6,311	21.2
Tolland	1,036	21.4
Derby	7,635	21.7
Ashford	761	21.7
Washington	1,792	21.7
Madison	1,504	21.7
Scotland	476	22.1
Killingly	4,036	22.6
Cornwall	1,191	23.2
Voluntown	900	23.2
Farmington	4,272	23.7
East Granby	678	24.1
West Hartford	3,000	24.3
Wallingford	8,639	24.5
Glastonbury	4,140	24.8
Total population	82,208	
TOWNS AND CITIES WITH RATE 25–30		
East Lyme	1,868	25.1
New London	16,980	25.1
Windham	10,132	25.3
Hamden	4,514	25.6
Southington	5,832	25.8
Lisbon	675	25.9
Huntington	5,334	26.3
Westport	3,971	26.4
Stonington	8,326	26.4
Naugautuck	9,892	26.5
New Hartford	3,385	26.7
Redding	1,443	26.8
Ansonia	12,331	26.8

Community	Average Population 1890–1907	Average Typhoid Fever Rate 1890–1907
Kent	1,245	27.0
Thomaston	3,282	27.0
Plymouth	2,726	27.1
Brookfield	1,037	27.4
Waterford	2,867	27.7
Orange	6,626	27.8
Andover	387	28.1
Middletown	17,143	28.2
New Britain	26,823	28.6
Windsor	3,515	29.0
Norwalk	19,563	29.2
Putnam	7,224	29.3
Manchester	10,245	29.3
Bethlehem	568	29.5
Total population	187,949	
TOWNS AND CITIES WITH RATE 30–40		
Oxford	944	30.1
Old Saybrook	1,442	30.3
Bozrah	830	31.1
Bloomfield	1,482	31.4
Clinton	1,421	31.5
Danbury	19,474	31.7
Enfield	6,774	31.9
Somers	1,565	32.1
Haddam	2,027	32.5
Hebron	1,020	32.6
Branford	5,518	33.0
Woodstock	2,127	33.6
Brooklyn	2,400	34.0
North Canaan	1,786	34.9
Simsbury	2,060	35.3
New Haven	104,730	35.4
Stamford	18,365	36.1
Ridgefield	2,567	36.3
Bethel	3,338	39.5
Total population	179,870	
TOWNS AND CITIES WITH RATE 40–50		
Sterling	1,086	40.6
Hartford	75,857	40.8
Stafford	4,333	41.7
Sherman	658	41.9
Waterbury	48,448	42.1
Bristol	9,304	43.1
Eastford	529	43.4
Hampton	630	44.1
Killingworth	641	44.5
East Hartford	6,113	45.5
Ledyard	1,228	46.1
Watertown	2,983	46.1
Total population	151,810	
TOWNS WITH RATE OVER 50		
Durham	880	50.8
Cromwell	2,024	52.6
Roxbury	1,064	55.3
New Fairfield	596	72.6
Total population	4,564	

Here again, as in Massachusetts, we find some of the smallest communities among those having the least typhoid fever mortality. If the word "rural" has any meaning, it is certainly applicable to many of these small communities in which the typhoid fever rate has over many years been exceedingly low. It is true that an equal number of communities of similarly small population may be found among those groups having higher death-rates. But while it is easy to account for this fact by the occasional importation of one or more cases, it is not easy, it is rather impossible, to account for the prolonged absence of the disease from purely rural communities if typhoid fever is in fact a rural disease, i.e., a disease of rural origin and rural habitat.

The quantitative relation of population to typhoid fever in Connecticut is well brought out in the following table from which it appears (in confirmation of the Massachusetts results given on p. 174) that the lowest rates occur in the smallest communities. So likewise do the highest rates; but while we have between rate 0 and rate 10 a population of 32,508 in communities under 5,000 population, we have at rate 50 and higher only 4,564 souls in communities of 3,000 or less. Again, while it is true that the largest groups of the more rural population (under 1,000) is between rate 10 and rate 15, the largest urban group is at rate 30–40. These figures surely do not indicate that typhoid fever is a rural disease.

CONNECTICUT COMMUNITIES ARRANGED BY POPULATION GROUPS AND ANNUAL TYPHOID FEVER DEATH-RATES FOR THE YEARS 1890–1907, INCLUSIVE.

TYPHOID DEATH-RATES AT OR BETWEEN	AVERAGE POPULATION OF COMMUNITIES, 1890–1907						
	Under 1,000	1,000–2,000	2,000–3,000	3,000–5,000	5,000–10,000	10,000–25,000	Over 25,000
0	2,663	0	0	0	0	0	0
0–5	0	0	2,764	3,450	0	0	0
5–10	1,719	7,033	7,160	7,719	0	0	0
10–15	7,713	11,923	9,766	19,742	0	0	67,676
15–20	5,357	12,394	9,872	20,066	14,429	35,932	28,176
20–25	4,975	10,727	5,146	19,484	30,111	11,865	0
25–30	1,630	5,593	5,593	18,682	43,234	86,394	26,823
30–40	1,774	8,176	11,181	3,388	12,292	37,839	104,730
40–50	2,458	2,314	2,983	4,332	15,417	0	124,305
Over 50	1,476	1,064	2,024	0	0	0	0
Totals	29,465	59,664	56,489	96,806	115,483	172,030	351,710

It will be remembered that the Massachusetts results indicated that previous to 1890 typhoid fever was far more truly than since that time "a rural disease" (p. 165). The following table reveals the same fact for Connecticut communities and proves beyond peradventure that an astonishing change in urban and rural typhoid has occurred since about 1882. This table should first be studied by itself and then its last column (of 8-year averages) should be compared with the data for 1890–1907 on the table previously given:

TYPHOID FEVER DEATH-RATES (PER 100,000 OF POPULATION) IN CONNECTICUT COMMUNITIES GROUPED ACCORDING TO POPULATION. COMPUTED FROM THE CONNECTICUT STATE REGISTRATION REPORTS, 1882–1889, INCLUSIVE.

POPULATION GROUP	AVERAGE POPULATION 1882–1889	RATES BY YEARS								
		1882	1883	1884	1885	1886	1887	1888	1889	Average Rate, 8 Years
Under 500 persons...	2,549	44·6	0	79·5	36·0	350·7	0	44·3	93·0	81·0
500 to 1,000.........	25,390	71·7	52·5	45·9	16·9	46·3	35·0	41·6	44·2	44·3
1,000 to 1,500.......	37,774	58·5	50·1	20·4	46·3	26·2	27·4	43·7	34·9	38·4
1,500 to 2,000.......	35,516	35·5	40·0	44·7	56·5	61·4	20·5	37·4	49·6	43·2
2,000 to 3,000.......	61,938	50·0	37·1	28·3	22·6	25·5	23·7	43·3	35·3	33·2
3,000 to 4,000.......	62,605	43·4	41·1	28·6	31·4	37·1	17·9	51·1	47·3	37·2
4,000 to 5,000.......	23,355	187·8	59·0	73·9	22·2	35·1	42·4	56·7	37·1	64·3
5,000 to 8,000.......	78,656	56·3	39·1	41·1	33·1	40·1	32·0	50·9	40·9	41·9
8,000 to 10,000.......	23,533	29·5	92·2	40·5	66·1	30·1	36·8	43·2	27·5	45·7
10,000 to 15,000......	57,031	35·1	28·1	25·6	14·7	14·6	23·1	18·9	21·2	22·4
15,000 to 25,000......	95,630	53·0	72·3	37·7	32·7	31·9	25·9	23·5	46·7	40·5
25,000 to Bridgeport..	61,413	27·2	5·7	49·7	38·1	27·5	34·7	27·9	24·2	29·4
Hartford and New Haven............	124,696	47·9	38·5	58·2	30·8	36·4	24·7	48·2	37·0	40·2
The state.........	690,086	49·6	44·0	40·7	32·5	34·6	27·1	40·4	38·3	38·4

Population calculated from U.S. Census figures.

Grouping the Connecticut communities according to their typhoid death-rates for the period 1882–89, brings out clearly the excessive incidence of typhoid fever in the towns below 5,000 population. A comparison of this table with the corresponding one for 1890–1907 shows a relatively greater decrease in typhoid fever mortality during the later period of our study for towns below 5,000 population than for the more urban communities above 5,000. In the group comprising the largest cities (over 25,000) a majority of the population was above "rate 30" in both periods. In the next two groups (5,000–10,000 and 10,000–25,000) a majority of the population was above "rate 30" in the earlier period and above "rate 25" in the later. More than half of the population of the groups below 5,000 was above "rate 30" for 1882–89 but the dividing rate had dropped to "rate 20" in 1890–1907. It appears then that in the 25 years under consideration the typhoid fever mortality of the large cities of Connecticut has remained nearly constant, but that since about 1890 there has been a slight decrease in the typhoid rates of the communities of middle size and a considerable decrease in typhoid rates in the small towns.

CONNECTICUT COMMUNITIES ARRANGED BY POPULATION GROUPS AND TYPHOID FEVER DEATH-RATES (PER 100,000) FOR THE YEARS 1882–1889, INCLUSIVE.

Typhoid Death-Rates at or between	Average Population of Communities, 1882–1889						
	Under 1,000	1,000–2,000	2,000–3,000	3,000–5,000	5,000–10,000	10,000–25,000	Over 25,000
0	4,256	2,817	4,586	0	0	0	0
0–10	0	1,394	0	0	0	0	0
10–15	0	4,967	9,927	3,352	0	13,642	0
15–20	3,784	4,383	4,767	3,998	13,144	28,203	0
20–25	2,651	2,873	7,554	11,169	23,416	0	39,883
25–30	1,884	2,324	13,131	10,474	9,124	13,719	0
30–40	942	25,012	7,426	18,079	7,000	58,540	76,521
40–50	4,264	11,847	2,225	10,642	5,729	32,202	47,925
50–75	4,321	9,932	9,725	26,004	29,863	0	27,383
75–100	2,990	4,540	0	4,546	5,343	0	0
Over 100	2,319	1,538	2,410	0	6,978	0	0
Totals	27,417	71,627	61,751	88,265	100,597	146,306	191,712

6. EVIDENCE DERIVED FROM THE VITAL STATISTICS OF THE STATE OF NEW HAMPSHIRE.

Lastly we have carefully considered the vital statistics of the state of New Hampshire, comprising a number of communities closely similar in many respects to those of the contiguous state of Massachusetts and therefore not very different from those of the nearby state of Connecticut, but having a much larger proportion of its population scattered over a large area in smaller communities. There is also considerable difference in the economic and industrial conditions of New Hampshire communities, since manufacturing, which is so prominent in Massachusetts and Connecticut, plays a distinctly less important part in New Hampshire. All this means that New Hampshire is, on the whole, a more rural state than either of the others and that it has more of its population living under strictly rural, i.e., country, conditions. The population of New Hampshire, smaller than that of Massachusetts, is distributed over a slightly greater area, and is, accordingly, a sparser and less concentrated population.

In the following table we present certain vital statistics of New Hampshire arranged in a form similar to that employed above for the states of Massachusetts and Connecticut, and fortunately also, like these, based upon trustworthy registration reports:

YPHOID FEVER DEATH-RATES (PER 100,000 OF POPULATION) IN NEW HAMPSHIRE COMMUNITIES GROUPED ACCORDING TO POPULATION. COMPUTED FROM THE NEW HAMPSHIRE STATE REGISTRATION REPORTS, 1890–1907, INCLUSIVE.

Population Group	Number of Communities	Average Population 1890–1907	Rates by Years																		
			1890*	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900*	1901	1902	1903	1904	1905	1906	1907	Average Rate, 18 Years
Less than 500 persons	51	15,520	35	18	36	18	30	68	31	6	13	13	20	27	..	7	35	7	14	14	21.8
500 to 1,000	81	57,810	27	49	27	22	39	15	29	10	16	21	24	16	14	18	11	5	16	5	20.2
1,000 to 1,500	43	51,790	37	17	17	17	17	10	27	10	21	23	19	15	13	19	21	13	12	8	17.6
1,500 to 2,000	24	41,130	40	58	40	22	37	20	25	20	19	19	36	34	17	12	19	21	12	21	26.2
2,000 to 3,000	13	31,430	25	25	13	16	38	10	13	13	25	10	3	16	22	29	..	6	25	9	16.5
3,000 to 4,000	7	23,760	58	57	51	64	18	4	31	22	38	54	41	12	20	55	16	4	30	19	33.0
4,000 to 5,000	2	9,610	12	36	36	..	68	22	33	54	11	10	40	..	20	10	..	19	9	9	21.6
5,000 to 8,000	3	18,840	63	25	48	59	17	11	39	11	27	16	5	20	30	15	43	14	14	18	26.4
8,000 to 10,000	3	26,080	33	28	12	36	36	20	35	27	15	4	11	19	19	15	15	18	11	11	20.3
10,000 to 15,000	2	23,660	18	22	31	26	17	17	13	13	25	17	25	29	29	25	12	25	33	28	22.5
15,000 to 25,000	2	37,450	30	54	24	18	23	33	32	12	21	9	5	11	13	13	15	11	18	3	19.2
Manchester	1	55,060	34	42	11	29	47	41	39	23	26	20	16	15	13	15	21	17	9	9	23.7
The state	232†	397,110	33.9	37.9	25.7	26.0	31.8	21.7	28.7	16.0	21.7	18.5	19.4	18.1	16.7	19.0	16.9	13.2	15.7	11.4	21.8

* Census years. Populations for intervening years estimated by method of U.S. Census.

† Two towns are omitted on account of changes in incorporation; also certain unincorporated places; total population thus omitted, 4,970.

From the above data we have prepared Fig. 5, in which the same method of presentation is used as for the other states, but in which both vertical and horizontal scales differ from those employed for Massachusetts and Connecticut.

Fig. 5 shows at a glance that the distribution of typhoid fever mortality in this state is distinctly different from its distribution in Massachusetts and Connecticut. The death-rates for the various groups show marked irregularity, the minimum, for example (16.5 for communities of 2,000 to 3,000) standing directly next to the maximum (33 for communities of 3,000 to 4,000). In general, however, the death-rates at both ends of the population scale are low, while the rates are relatively high in the communities of medium size, notably those of 1,500–2,000, 3,000–4,000, and 5,000–8,000.

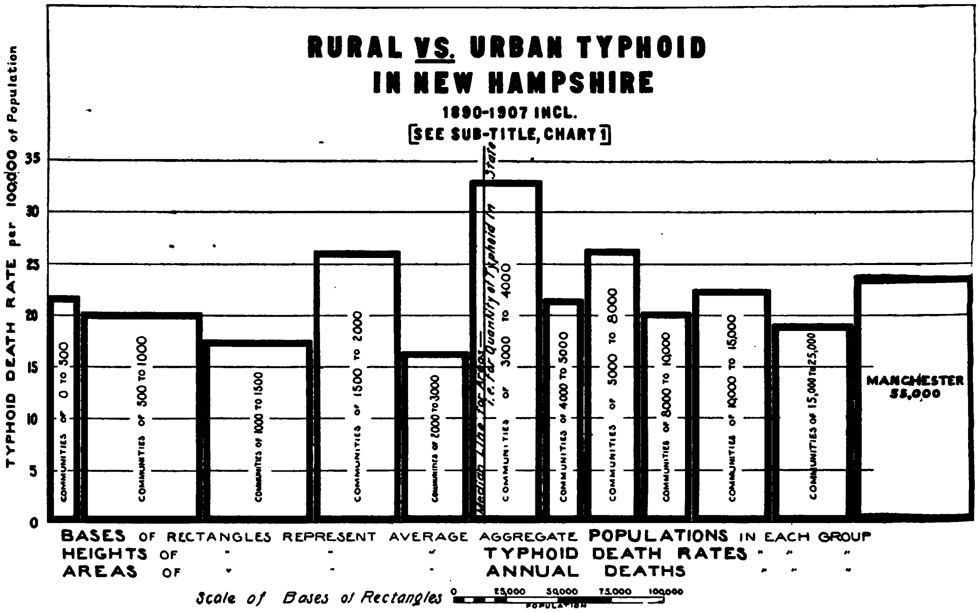


FIG. 5.

Considering the areas of the rectangles, that is, the total deaths from typhoid fever, the distribution appears to be fairly regular, the position of the median line indicating that about as many deaths occurred in places of more, as in those of less, than

3,000 population. This finding is quite different from that in Massachusetts and Connecticut, as will readily appear by comparing the median lines for those states with that for New Hampshire. At the same time the greater proportion of population in the smaller and more rural communities in the case of New Hampshire must not be overlooked. In New Hampshire, apparently, typhoid fever cannot be said to prevail to any decidedly greater extent in either group, rural or urban.

The fact that it appears to have been relatively abundant in communities of medium size, as noted above, is precisely what theory would lead us to expect in a state of this kind. We should not expect to find typhoid fever abundant in strictly rural districts of very small population and consisting chiefly of scattered farmhouses. Neither, on the other hand, should we expect to find it abundant in cities like Manchester, Concord, and Nashua, which are well known to have water-supplies of excellent quality and boards of health of good repute. We should rather look for it exactly where we find it most prevalent, namely in places which are neither strictly rural nor strictly urban, where people are perhaps gathered closely together, but as yet without the advantages of strictly urban conditions. In such places, as we have repeatedly intimated, modern conveniences, such as public water-supplies and sewerage systems, have often not yet come, although they are greatly needed, while the conditions are those of aggregation rather than segregation and carriers as well as unfavorable sanitary conditions naturally make for the prevalence of typhoid fever.

7. RECAPITULATION AND CONCLUSIONS.

In the first section of the present paper we have drawn attention to the discrepancy which appears to us to exist between the logical corollaries of our modern knowledge of the origin and distribution of typhoid fever on the one hand, and prevalent opinion concerning the relative frequency of typhoid fever under urban and rural conditions on the other.

In the second section we have cited at considerable length various authors, some of whom assert that typhoid fever is a rural disease and others of whom appear to be equally confident that it is an urban rather than a rural disease.

In the third section we have discussed at some length the terms "urban" and "rural" in order to obtain a sound basis for such investigations as appear to us to be required.

In the fourth section we have described in detail a very careful and, as we believe, a thorough statistical investigation of the actual facts concerning the distribution of typhoid fever mortality in country and city in the state of Massachusetts; and in the two following sections, similar studies of the vital statistics of the contiguous states of Connecticut and New Hampshire.

It now only remains to bring together what we conceive to be the results of all these studies and to draw from them such deductions as are justified.

The first and most important conclusion to which our investigations lead is, that if we take as long a period as 18 years previous to 1908, typhoid fever cannot be said to be in any real and true sense of the word distinctly a rural disease, that is to say, preeminently a disease of small communities composed of isolated or scattered dwellings distributed over country districts.

A second and perhaps equally important result is that this general finding, while it holds good for the period 1890–1907, is not true if we consider only the preceding decades. In other words, about 1890 a remarkable change appears to have taken place in the incidence of typhoid fever mortality—at least in Massachusetts and in Connecticut—such that whereas previous to that time typhoid fever deaths were more prevalent in proportion to the population in the country than in the city districts, after that time and measured in that way typhoid fever became distinctly a more urban than rural disease. For this discovery we were in no wise prepared when we began our studies and we are the more gratified to have developed the fact because it enables us to harmonize what would otherwise have been our discordant results with the studies and statements of earlier authors.

It is not easy to account for this change, and we might perhaps better leave our results as they stand, without trying to explain them. Piqued by curiosity, we have, however, sought to find some explanation of them, first, for the fact—for it appears to be a fact—that previous to 1890 typhoid fever in Massachusetts and Connecticut evidently was a rural rather than an urban disease, second, for the change which then took place, and, third, for the present state of affairs in which typhoid fever (in Massachusetts and Connecticut at least) appears to be an urban rather than a rural disease.

It is hard today to see why typhoid fever should ever be, or ever have been, more abundant in country than in city. The very fact of segregation of population tends to make infection difficult, and without infection there can be no typhoid fever. It was this *a priori* reasoning which originally led us to undertake the present investigation, for this view is opposed *in toto* to the popular belief that typhoid fever is a rural disease, and, as we have stated at the beginning of this paper, it was this contradiction between rational theory and traditional opinion which caused us to set to work to discover the truth.

We know that before 1890 typhoid fever in Massachusetts and Connecticut was apparently more a rural than an urban disease, not only from the studies reported in the present paper but also from the investigations of Dr. Abbott and Dr. Derby. The question arises (1) Why was this the case? And also, (2) What conditions of *infection*, *virulence of microbes*, or *vital resistance* (the three factors of any infectious disease) prevailed before the year 1890 or thereabouts which were afterward so altered as to reverse the incidence of the disease?

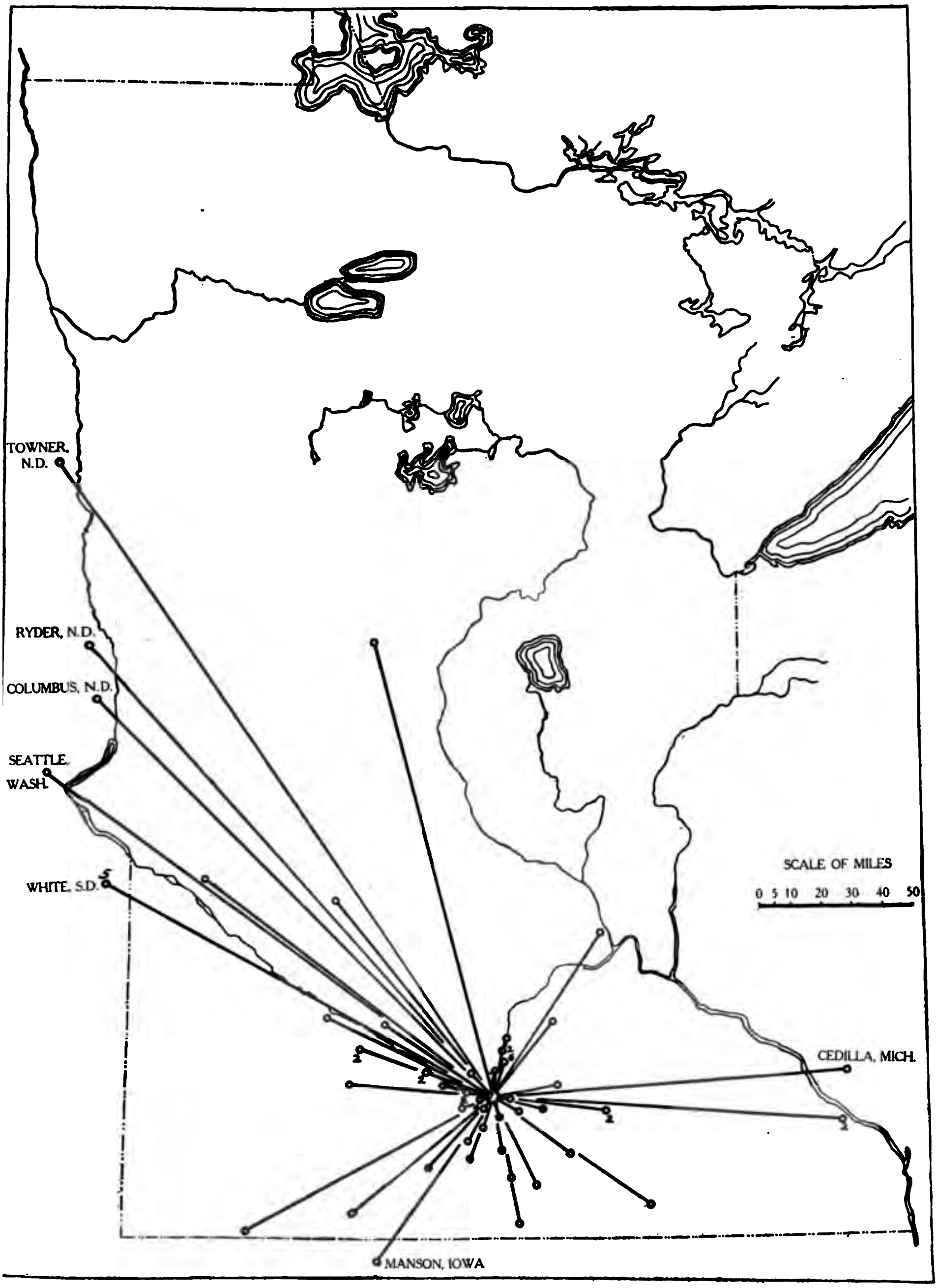
There is no good reason to assume for the years previous to 1890, any greater virulence of typhoid microbes in the country than in the city, or any greater vital resistance in the city than in the country, nor is there any reason for assuming any change in relative virulence or relative resistance since that time. The only possibility that has even a shadow of reasonableness is that somehow the relative conditions of infection have changed. But if so, how? There is one possible explanation which, though not wholly satisfactory, is worthy of note:

The Civil War of 1861–65 caused the germs of typhoid fever to be carried as never before or since into many a rural home and many a rural hamlet. Some, perhaps many, of those who came back from the war worn and weakened were doubtless "typhoid carriers," and some doubtless long remained such. It is possible that the infection thus widely planted continued to be felt during the 30 years between 1861 and 1891, but by the latter date had become mostly attenuated or extinct. If this were true we should only have to explain the relatively higher mortality in the rural regions during the period. And this might be done by supposing (what was doubtless true) that various rural conditions, such as more frequent failure to recognize or attend to the disease, less skilful diagnosis, or nursing, or medical attendance, or more contacts *within families*, etc., existed in the more rural districts.

Assuming the truth of this hypothesis of lingering military or camp infection from the Civil War, it is comparatively easy to account for all the facts. The presence of high typhoid rates in the country districts during the periods studied by Drs. Derby and Abbott—a condition normally impossible—would be due to the return of infected soldiers. The same cause should also produce at the same time high typhoid rates in cities, but some difference in favor of a lower rate in the cities might have been due to early diagnosis, better care, hospital treatment, etc. The gradual decline in both urban and rural typhoid rates might be due in part to the gradual exhaustion of the original infection. A more rapid decline in the country than in the city might be expected to occur because of the comparative isolation of the patients and the absence of opportunities for contact infection outside infected families or houses.

On this theory also we have an explanation in whole or in part of the origin of the high typhoid fever death-rate which has long been a reproach to the entire United States. The prolonged persistence of that high rate, however, could hardly be due wholly to such original infection. Other factors, such as polluted water, polluted milk, promiscuity, etc., must be called in to explain such persistence, and these would be much more likely to be effective under urban than under rural conditions.

The effect of certain other great movements of the population during the period covered by our study deserves careful consideration, namely, *immigration* and *urbanization*, or the growth of cities more or less at the expense of the country.



Map of Minnesota showing the position of Mankato and how typhoid cases were radiated from it during the epidemic.

It is probably true that during the period under consideration immigration of Europeans free from typhoid fever was directed largely to the more urban portions of New England, and this was probably especially true during the earlier period, which would only tend to bring out more clearly the phenomenon of typhoid fever excess in the rural districts. In the later years of the period more of this typhoid-free population has perhaps gone to the country and may thus have helped to accentuate that decline in rural typhoid which we have repeatedly noted. Obviously, the general effect of such immigration would be to dilute the population with typhoid-free material and thus help to lower the general rate. It is, however, quite impossible to be certain how far the inflow of immigrants from Europe has influenced, if at all, the American death-rate from typhoid fever.

The other great movement, from the country districts into the cities, has been equally marked and very likely equally influential. But here also it is impossible to say precisely what the effect of this movement upon typhoid fever incidence and mortality may have been.

It will doubtless appear strange and incredible to many not only that typhoid fever is today an urban rather than a rural disease, but also that it is quite as often spread from town to country as from rural to urban districts. We are therefore glad to be able to refer for an illustration and a striking example to the epidemic of 1908 at Mankato, Minn., first described by Professor F. H. Bass in the *Engineering News* of February 11, 1909 (61, p. 151).

In the Mankato epidemic, which was due to polluted water, 72 cases with five deaths were found in the surrounding country which had derived their infection from the polluted water-supply of Mankato. A diagram of some of these was originally published by Professor Bass (*op. cit.*) in which the sites of the cases are connected with Mankato by lines radiating from the city as a center to the various rural points, some near and some very remote, where the cases occurred. The diagram is so striking and so instructive that we have ventured to reproduce it here. A complete account of the epidemic and another map appeared in this *Journal* for 1911, 9, p. 422, Fig. 6.

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COLD STORAGE AND PUBLIC HEALTH.[1]

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Instead of reading a formal paper, because formal papers are better read than listened to, I want to make an address and to introduce this interesting symposium,—since I have that honor and privilege,—with a few very fundamental considerations.

One is tempted to go into the historical side of the matter and show how, in his own boyhood, when there was no such thing as formal cold storage, meat and milk were hung down in the well, and how, often-times, when spring came, there were very few or no vegetables other than potatoes and cabbages available for the ordinary household. But that is not the subject of my paper. Mine is the more difficult matter of trying to correlate cold storage with public health, and I shall try to stick closely to my text. The reference that I have made, however, shows that before we had cold storage, there was great difficulty in providing suitable food and in keeping that food, especially in temperate climates, which have seasonal changes. Now, at that time, the temptation to keep food too long was very great and the necessity of going without much of the good food that we get today was imperative, so that in the past, without cold storage, the public health was endangered by the temptation to use food that had not been properly kept, and by the lack of sufficient variety at certain seasons. There was also the danger of over-eating of salted foods and we all know how much of the history of scurvy comes along that line. Scurvy was cured in the first instance, you remember, by lime-juice, not by cold storage, but who hears of lime-juice today except in the British Navy, where the men are still familiarly called lime-juicers by the people in other navies and by merchant seamen. Now, under conditions like these came cold storage, and the result is that we may have today at any season, anywhere, fresh food, that is to say, not salted food, and in the greatest possible variety. It is, however, frequently alleged by easy talkers on this subject and by the newspapers that follow on their heels, that a great deal of sickness comes from cold storage food. But remarks of that kind though easy to make, are very difficult to prove. Mr. A. eats a meal containing some cold storage material and he feels bad afterwards. He naturally lays this to the cold storage food. But, ladies and gentlemen, *post hoc* reasoning has always been the bane of the medical profession and I sincerely trust it will never be allowed to become the reproach of the sanitary profession. We want proofs, we want facts, and not suppositions or mere *post hoc* reasoning. I have taken pains to run down a number of alleged cases of poisoning by cold storage food, and not one of them has proved to be of any consequence, such as would enable it to stand in a court of law. I have no doubt that some cold storage food is bad. I have no doubt that some food that has not been in cold storage is bad. I have no doubt that some food is put into cold storage which was bad when it was put in and bad when it came out, possibly a little worse when it came out than it was when it went in, but not much, and so I am very skeptical on this matter of injury to the public health by cold storage. On the contrary, I believe that one of the greatest blessings that ever befell the human race was the discovery of the principle and practice of cold storage. I would even go so far as to say that we could not, today, maintain in any comfort, the great cities that dot the globe, if it were not for this wonderful system of cold storage; and so, as I say, I have yet to discover any appreciable ill effects from cold storage upon the public health, while I can discover any number of blessings to the public health from an abundant dietary, from cheaper food than would otherwise be practicable, and from the substitution of fresh material for material which was spoilt or which was salted.

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[1] Stenographic report.

Now, it is commonly allowed that much of what I am saying is certainly true, but that there are many abuses in connection with cold storage: first, sanitary abuses, which affect the public health, and second, financial abuses, which affect the public purse and indirectly, therefore, the public health. Of course, if bad food is put into cold storage, as I have already said, the cold storage won't improve it any and will probably allow it to deteriorate slowly, meantime; and I believe that instead of taking so much pains about what comes out of cold storage, the proper place for health men to operate is on the placing of things in cold storage. If we could keep out of the cold storage warehouses that food which is just on the edge of spoiling and is put in there only to save it for a little time, we should make a great gain. We might not save many lives, but at any rate, we should improve the quality of the food output from those warehouses, and I feel strongly that we ought to give more attention than we now do to that end of the subject.

When it comes to the matter of labeling, when it comes to the matter of the length of time in storage, these are technical points that I have no doubt other speakers will touch upon. I have strong feelings and convictions upon them myself, but it is unnecessary to go into them at any length here. I do believe, however, that the time element is comparatively unimportant and that all the attempts, largely political, which have been made to limit the time of storage to three months or six months or nine months, are futile and of little consequence for the public health,—of no consequence to the public health. They may be of some consequence to the public purse, but nature or the season limits these things and the proper basis should be seasonal periodicity. A year is the natural and should be the legal limit in climates like ours, because then the next crop comes into competition with the old crop, and if any limit is needed,—which I do not believe,—then it would be natural and proper to have it the limit nature has set to production. I do not believe that any limit is necessary and my reason is this, that the accumulation of the charges for storage, interest, taxes and all those things, will, in 999 cases out of 1,000, oblige the packer of foods in cold storage to get rid of them, even at a great loss, before the next season's crop comes in. Gambling in food stuffs has always been one of the most dangerous things in the world for the gambler, and gambling in cold storage, in my judgment, is no exception. However, I am wandering away from my subject, which is the influence of cold storage on the public health. I believe,—to sum it all up, and I need not make a long talk, for the subject is very simple,—that, by cold storage today, rightly supervised by boards of health, as it should be, the public health has been and will be immensely promoted. I believe that the public health will also be promoted indirectly through the cheapening of costs. Secretary Wilson, in one of his publications not long ago, said that cold storage was undoubtedly a great benefit to the human race, but it was a question whether it did not increase the cost of food. The facts are, as studied by economists, that in all probability cold storage cheapens the cost of food and in two ways: first, by saving what would have been lost at one season and keeping it over to another, when prices would have been much dearer than if it had not been kept and the supply at the later period increased, and secondly, by encouraging production. Take a farmer in the West, who is producing anything for cold storage or anything which is eligible for cold storage. Suppose there were no cold storage, he must sell forthwith for what he can get. The cold storage warehouses have enlarged his market, and have thus encouraged his production. Do away with cold storage or interfere too much with the time limits, and you cut off the demand, and if you cut off the demand once for even one season, you diminish the supply in the next. If cotton is high this year, the farmers plant more cotton next year. If cotton is low this year, they plant less cotton next year. If fewer things to go into cold storage are demanded this year or if there is no cold storage, the farmers will go out of the raising of those particular things and the supply will be diminished, and it is the supply, in the long run, which regulates prices. Now, if prices get high, the public health suffers, and I, for one, in these days of so much talk about the high cost of living with so much truth in it, am very eager that we, as sanitarians, shall not too much increase prices by unwise or needless propositions in regard to foods and drink for man. It is very easy, by making sanitary requirements too difficult, by hampering the farmer in a thousand ways, it is very easy, I say, to discourage him and lead him to go into some other line of production that diminishes supply and makes prices jump up. When prices rise, the poor get poorer food; and when the poor get poorer food, the public health suffers. And so, Mr. Chairman, without stopping to repeat or strengthen any of these remarks, I may simply recapitulate by affirming, in the first place, that there is, so far as I know, no good evidence that cold storage products are injurious to the public health. Of course, there have been cases, very many cases, of alleged injury, but these injuries were not due, necessarily, to cold storage. They may have been due to the poor quality of the food at the outset,—and cold storage cannot redeem bad food. In the second place, those cases are very few and far between, anyhow. I saw, for example, this winter a statement that a man in a neighboring city to mine had died from eating a cold storage egg. I ran the thing down and found that the man had not died from the egg at all; he had apparently died from pancreatitis, and it was a newspaper exaggeration, pure and simple. I believe, on the contrary, that cold storage has improved the public health and it is capable of still further improving it, immensely improving it. I believe, however, that, like everything of a big sort nowadays, it needs regulation and that the public has a right to know what it is getting and under what conditions. The "rule of reason" applies here as everywhere,—reasonable time limits, reasonable labeling, and especially the safeguarding of food that goes into storage, to see that none but good food goes in; these appear to me to be the main points for proper protection of the public health.

THE FALLACY OF TESTING FOOD MATERIALS BY ANIMAL INOCULATION

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Some years ago it was seriously proposed to test the purity and salubrity of drinking-waters by means of animal inoculation. Portions of the water to be examined were cultivated in sterilized bouillon at the body temperature, and the resulting cultures after a stated time were inoculated into guinea-pigs, rats or other test animals. If these sickened or died the water was condemned. Fortunately, since some sense of humor still remained among sanitarians, a proposition so absurd was soon laughed out of court. From time to time, however, this discredited "test" is again gravely brought forward even for water, but more often nowadays for some other form of food or drink, such as eggs, oysters, ice-cream, gelatin, catchup, etc. One of the latest examples — but probably not the last — of such proposed employment of it is for frozen eggs, attacked originally because of alleged "decomposition" as indicated chiefly by richness in bacteria and the presence of numerous *Bacilli coli,* but afterward by inference as dangerous to health because sometimes fatal to animals on inoculation.

The frozen eggs involved in a recent case with which I happened to be connected were entirely sweet and agreeable in taste and odor when thawed. Similar eggs had been used for many years and in large quantities by bakers in pies, cakes, custards, etc., not only without perceptible injury or complaint of any kind but with the greatest convenience, economy and satisfaction.

Disregarding these results of long-continued experience, it remained for certain government bacteriologists and physicians to discover that such eggs were really "decomposed" and dangerous to health, first, because of the large numbers of bacteria which they contained; second, because of the presence among these of some streptococci and many *B. coli*; third, because when the raw melted egg was inoculated into test animals some of these died; and, fourth, because after the death of such animals certain supposedly objectionable bacteria, *B. enteritidis, B. pyocyaneus, B. alcaligenes,* etc., were in some instances found in the blood.. In other words, over against the long experience of the trade and of consumers of the eggs yielding wholly favorable results of innumerable feeding experiments on human beings, it is now proposed to set up a scanty experimentation on animals; and that not by feeding them as man is fed, and not after cooking of the food materials in question, such as mankind employs, by which process most of the microbes present are destroyed, but by direct injection of large amounts of the raw and uncooked egg substance subcutaneously or into the delicate peritoneal cavity of certain lower animals. To the best of my knowledge and belief, the eggs which it is thus sought to condemn were good and wholesome food, eaten raw or cooked.

It is time to protest against "tests" of this sort which are obviously both irrelevant and misleading, for conclusions based on facts of one order cannot properly be applied to problems of a different order. To realize how unscientific and absurd is the proposal under consideration it is only necessary to recall some simple elementary facts and details.

The body of the higher animals, as every one knows, is not a solid mass completely enclosed by the skin, but a semisolid bundle of tissues tunnelled by a long and folded tube, the alimentary canal or food-tube. This tube possesses its own special walls, expressly adapted for preventing raw food and other foreign substances from entering the real body—which lies between the food-tube and the skin—until such substances have been digested and made ready for absorption. Within this tube, food, whether raw or cooked, is chemically treated until some of its components — but only some — are admitted into the body proper, the remainder being held in the tube, moved onward and eventually cast out.

This fundamental process of preparation or digestion, normally absolutely inevitable, and carefully and even elaborately conducted, is in subcutaneous or intraperitoneal inoculation entirely omitted, so that the latter procedure is in no wise comparable with the former. Hence the results, also, of the one process bear no natural or necessary relation to those of the other. As for the preparatory process of cooking, everyone knows that this not only ordinarily causes profound chemical and physical changes but also destroys most microbes and many toxic organic substances; so that here again the thrusting of raw foodstuffs into the real body becomes a crude and severe procedure, a kind of rough surgical interference, totally different from the normal taking of the same materials into the body by way of the food-tube — perhaps already cooked.

In order to see just where we stand in this matter, we have only to compare the effects of substances of various kinds when taken by the mouth with those of the same substances injected into the real body hypodermically or intraperitoneally. We shall naturally think first of drugs, since it is in the use and abuse of these that resort is oftenest had to direct inoculation. We shall begin, perhaps, with morphin, remembering the familiar fact that a quantity of this drug, which taken hypodermically would quickly kill, can be taken with impunity by the mouth. The same thing is true in a general way of most drugs and poisons, the arrow-head poison (curare) of the South American Indians, for example, being often without marked effect when eaten, but highly poisonous when inoculated into the real body. Most alkaloids, and the toxins of diphtheria, tetanus, typhoid and other infections act either comparatively feebly or not at all when taken by the mouth, but with comparative severity by direct inoculation.

Passing from drugs, alkaloids and metals to beverages, we recall how different is the effect of brandy and other alcoholic drinks when taken through the mouth and when the same quantity is injected subcutaneously. Again, the germs of two of the worst diseases that afflict the human race, namely, lockjaw and anthrax, while extremely dangerous on inoculation, are comparatively innocuous if taken through the mouth.

As for any bad effects on health of the ordinary foodstuffs used from time immemorial by mankind, very little was heard until about 1890, and a careful investigation will show that the evidence of such bad effects accumulated since that time is mostly inconclusive and unsatisfactory. It seems likely that the evolution in the human race of the habit of discriminating among raw foods, and of using chiefly particular materials, such as certain meats, fish, eggs, fruits, nuts, etc., while avoiding others, has arisen as the result of long and hard experience—experience being only another name for long-continued individual or racial experimenting.

Panum (1856), Selmi (1878) and afterward Brieger (1890) appear to be chiefly responsible for the popular belief that "ptomains" are common in spoiled foods, but both investigation and experience since their day have weakened rather than strengthened the idea of dangers of such poisoning. In point of fact, the whole subject of ptomain poisoning and of food poisoning in general stands to-day in great need of reexamination, and until the results of this are forthcoming we are justified in speaking and writing of either with the utmost reserve. When, remembering the enormous quantities of partially decomposed meats, eggs, fish, shell-fish, milk, fruits and vegetables eaten every day either raw, cooked, or half cooked, not only without apparent injury but with positive relish and advantage, we think at the same time of the infrequency of cases of ptomain poisoning proved or even alleged — when, for example, we think of the immense amounts of fermented or partially decomposed milk, buttermilk, ice-cream, meat, fish, game, cheese, sauerkraut, and the like, constantly consumed without inconvenience of any kind and with positive benefit, it is easy to see how extremely rare must be the occurrence of harmful substances in harmful quantities, at least during the earlier stages of decomposition or decay of ordinary food materials.

Returning now to the proper testing of the purity or salubrity of food materials, it is an old and true saying that the proof of the pudding "is in the eating" — not in its inoculation into animals. This latter test is irrelevant because unnatural, and hence for determining the purity or healthfulness of food materials absolutely worthless. If it may be used for one food substance it may be used for all, and the absurdity is obvious of seeking to determine the suitability of meats, eggs, milk, fish, etc., for human food by trying them on animals, and that not by feeding but by inoculation. Even that popular test in which we are advised to "try it on a dog" does not contemplate surgical inoculation, but only the ordinary process of feeding by the mouth.

Thus far I have entered no protest against the testing of food materials on the lower animals rather than on human beings, but as a matter of fact such experiments are only allowable when for some good reason they cannot be made — as in the case of eggs and other common foodstuffs they easily can be made—on human beings. Moreover, because of the wide differences between man and the lower animals any results of such experiments on the latter can be accepted for human beings, if at all, only tentatively and with much reserve. It is a significant fact that the lower animals do not appear to be susceptible to typhoid fever, either by inoculation or by feeding. Conversely, none of the diseases to which hens are susceptible appear to be transmissible to man.

What then, if any, we may ask, is the true significance of results obtained by the testing of food materials by the inoculation of animals? The answer is that if the animal survives and suffers no apparent inconvenience, it must be because no microbes or other substances were injected capable of doing that particular animal harm when taken in that dangerous fashion. This does not prove, however, that if the substance were taken through the mouth, no harm would have come, though it makes such a result unlikely, for the reason that the inoculation test is as a rule far more severe than the feeding test. If, on the other hand, test animals are regularly sickened or killed by such inoculation, then the meaning must be that microbes or other substances were injected which were harmful to those animals when administered in this way. But such a result does not prove the unfitness of the material tested for use as food, since the processes of cooking (a kind of external or artificial digestion) and of ordinary (internal or natural) digestion, absorption, circulation and cellular metabolism, may suffice to change it so extensively and to deliver it to the protoplasms of the body so transformed as to make of it, when taken by them in the ordinary way and at their own convenience, a totally different thing from the same material thrust on them in its raw state and whether they want it or not. In short, the mere sickening or death of animals inoculated with raw food materials throws no light whatever on the purity or healthfulness for food of the material injected. Moreover, the finding of this or that microbe in the body of animals after such inoculation neither proves that the microbe came from the food material injected, nor that, if it did so come, it would have survived the processes of cooking, digestion, absorption, etc., to some or all of which it would have been subjected if the material had been administered by feeding instead of inoculation. Finally, there is no proof that, if it had so survived, it would when administered by the mouth have done any harm.

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THE BACTERIOLOGY OF FERMENTATION AND PUTREFACTION IN RELATION TO THE CONSERVATION OF FOODS.

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THE BACTERIOLOGY OF FERMENTATION AND PUTREFACTION IN RELATION TO THE CONSERVATION OF FOODS.

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Read before the American Public Health Association, September, 1912, Washington, D. C.

Conservation of foods is in general accomplished by either the destruction or the inhibition of the bacteria which are certain to gain access to them. A consideration of the bacteriology of fermentation and putrefaction in relation to the preservation of foods would, if complete, contain the results of a large number of researches, and a very extensive list of so-called species of bacteria which investigators have described as important in connection with this subject. Since this is manifestly impossible in a short paper, it has seemed to me best to describe at the outset the types of substances available as food and to point out the character of the chemical change which each of these kinds of materials undergoes. In this way we may deal with the microörganisms as groups rather than as species, and the subject becomes less detailed and more easily considered.

Our staple articles of food are of particular value because of the occurrence in them of proteins, carbohydrates or fats which can be transformed by the enzymes of the alimentary tract into energy or matter directly available for the running and repair of the living mechanism. Of these, the proteins are the chief muscle-forming foods, while the other two are more quickly oxidized in the body and the energy is largely transformed into heat rather than modified into the tissue substance. Although we speak of each of these types of foods as an entity, in but few cases do we have any one of them entirely free from one or both of the others, a point which is of some importance in the consideration of questions pertaining to conservation. While especially thought of as food substance for higher animals, all these foods are subject to microbic action, that is, serve as food for the different kinds of germ life. The proteins and carbohydrates are of special importance from the standpoint of food preservation because they are relatively easily attacked or destroyed by microörganisms of different kinds, and especially by the bacteria, with the formation of cleavage products poorer or lacking in food value, depending upon the rate and amount of decomposition, and resulting finally in the total destruction or spoiling of the food. The fats, on the other hand, show considerable stability, at least toward bacterial activity, although they too may undergo decomposition by microörganisms to such an extent as to make them objectionable as food.

All the changes induced in food substances through the activity of bacteria or nearly related organisms may be grouped together under the general name of "fermentation." The term, as thus employed, is a general one, and embraces a large number of specific chemical changes induced by the organisms of different types. The products of these fermentations are very numerous and may be of widely different character. The foods in which carbohydrates predominate are in general acted upon by certain classes of bacteria or by yeasts and moulds with the formation of acids or alcohols as the final products of the fermentation. Along with the acid formation there may also take place the evolution of gases, particularly of carbon dioxide and hydrogen.

The protein-containing foods, on the other hand, are subject to fermentative processes of a widely different type and these processes themselves may be further placed in two groups according as the organisms involved are aërobic or anaërobic in character. Those decompositions of nitrogenous material in which products extremely objectionable in character and of vile odor are frequently formed are generally grouped under the name of "putrefaction" or "putrefactive fermentation." In some instances, particularly with aërobic bacteria, oxidation processes are carried out in which these offensive substances are formed in but small amounts and to these frequently the term "decay" is given, while the stronger term "putrefaction" is reserved for the anaërobic fermentations in which the malodorous products are most conspicuous and the oxidations much less complete. Certain classes of foods, as for example, the edible seeds of plants, which contain both carbohydrates and protein in considerable amount, are subject to both these types of change, the predominant one depending upon the character of the infection and upon the conditions of temperature and air supply. The substances rich in nitrogen and sulphur, that is, the proteins, through the agency of putrefactive bacteria give rise to basic or alkaline end-products, while the foods essentially carbohydrate in character give rise to acids. In both cases the changes go stepwise through a number of intermediate stages, these intermediate products consecutively diminishing in complexity so that, in general, the final cleavage products are mixtures of such simple substances as ammonia, carbon dioxide, sulphuretted hydrogen and mercaptans with amines and still more complex products of putrefaction. Organic acids, of weak types, may also be produced in small amounts and frequently these are at once neutralized by the basic or alkaline products which are likewise formed.

With the carbohydrates, the trend of the reaction is essentially that of hydrolysis, the splitting of sugars or starchy substances into simpler sugars, and the fermentation of these, with or without gas formation, to different acids, particularly lactic, butyric, formic and acetic acids. It may be further noted that proteins of different sources, or different proteins give essentially the same substances on decomposition.

Turning now to the organisms involved in these changes, we find that they may be grouped in a few groups more or less merging into each other and occurring around a few type species. Researches on putrefaction have been carried out for many years. Early investigations were made with mixed cultures of unknown species and their value lies chiefly in indicating the extent to which the decomposition processes may go on rather than for any information obtained as to the character of the inciting organisms themselves. The so-called Bacterium termo, a name which was early given to minute organisms found in decomposing matter, is now known to be of absolutely no value from the taxonomic standpoint. The organisms grouped under this general name were merely of minute size and occurred in putrefying materials, and undoubtedly consisted of many varieties or types of bacteria of small size which happened to occur together.

It was not until the work of Hauser, working with pure cultures, that the bacteriology of protein decomposition began to be elucidated. He discovered, or rather isolated, several kinds of organisms to which he gave the name Proteus, and among these, Proteus vulgaris, or as it is known today, Bacillus vulgaris, was apparently of the greatest importance. This organism is characterized by vigorous motility and marked proteolytic power; and occurs widely in decomposing organic matter. It has no spore formation but seems to possess great chemical activity, affecting a wide variety of substances, not only proteins, but also to some extent sugars, upon which it produces organic acids as well as carbon dioxide and hydrogen. Around this organism as a type form are grouped many others which are similar to it in character, except that they may vary in sugar fermenting power or in the ability to elaborate the same number of enzymes. In most of these, however, the secretion of invertase, rennet, lipase and trypsin takes place. A step further removed, but still nearly related, is a large group of organisms characterized by the power of rapid liquefaction of gelatin and by the formation of green fluorescent products. Best known among these are the organisms Bacillus fluorescens and Bacillus pyocyaneus of which many races or sub-types occur. Furthermore, these are more or less modifiable as to liquefying power and color production, depending upon the character of the food and the temperature at which they develop.

A step farther away are certain organisms of marked chromogenic power, such as Bacillus prodigiosus which, under certain conditions, gives rise to distinct putrefactive changes. The organisms of the hay bacillus type must also be grouped among those which are potentially proteolytic in character and capable of inducing putrefactive change. The organisms of the colon group may also be considered from the standpoint of their power to cause putrefaction. This great group which exceeds all others in the actual number of bacteria in the intestinal tract of warm-blooded animals presents to a more marked degree than the preceding groups the dual personality of being putrefactive and fermentative at the same time. Grown upon media free from carbohydrate and containing albumose or peptone, putrefactive change takes place. On the other hand, if certain carbohydrate foods are present and the temperature is a satisfactory one the fermentative or acid-forming function of the organisms become predominant, acids are produced in liberal amounts, and putrefactive change is checked. We may say, then, that the general result of the development of the colon bacillus and its nearly related species within the alimentary tract is to check intestinal putrefaction and to operate in opposition to the pronouncedly putrefactive types, while on food substances poor or lacking in sugars outside the body, its action is very likely to be putrefactive and destructive especially to secondary protein. Among the cocci, also, various kinds possess the power of inducing both putrefactive and fermentative change, so that a rather ill-defined group of this family, characterized perhaps by its acid-forming power on the one hand and its pathogenic power on the other, must be classed with the putrefactive organisms.

Most important of all the bacteria, from the standpoint of true putrefaction, is the group of anaërobic organisms of which the Bacillus putrificus of Bienstock is the type. To the organisms of this group may be ascribed the most rapid and thorough disintegration of proteins, hence, they may be called the true putrefiers. This organism (B. putrificus), which is anaërobic in character and produces drumstick-shaped spores is, according to Klein, the most important organism concerned in the decomposition of dead animal bodies. It is certainly one of the most vigorous organisms engaged in putrefactive change. Under anaërobic conditions it produces strong tryptic digestion or fermentation, and gives rise to amines as end products of the reaction. Closely related to this are three other strongly anaërobic types, Bacillus perfringens, Bacillus bifermentans sporogenes and Bacillus gracilis putidus. Of these three markedly anaërobic putrefactive types of organisms the last does not ferment sugar while the others prefer the presence of sugars and are able to break them down more or less completely. Undoubtedly here, as in most instances, the presence of large amounts of sugar would have a decidedly restraining action upon the putrefactive functions.

As with the aërobes, collected about these type forms are numerous intermediate or variant species, so that in any organic material undergoing a spontaneous, that is, "natural" putrefaction, the observer might find a great variety of organisms but few of which correspond absolutely to the type species which have been named.

The above mentioned groups of bacteria may be arranged in two great classes. First, the *true* putrefactive bacteria or *those which decompose native protein.* These include (*a*) all strong anaërobic bacilli; (*b*) Bacillus vulgaris; the organisms of the Bacillus fluorescens type; Micrococcus pyogenes; many spore-forming rods, among them soil bacteria especially belonging to the groups of Bacillus mesentericus, Bacillus subtilis, and Bacillus ramosus.

Second, those which decompose protein *cleavage products,* but because of lack of tryptic enzymes cannot break down native protein itself. These affect especially albumoses and peptone, hence are of less importance from conservation standpoint than the first group. Under this heading appear many organisms both of bacillus and coccus forms, some of which are strongly fermentative in character, as, for example, some organisms of the colon and lactic groups, B. prodigiosus, Micrococcus, etc. With a single exception these are all aërobic or facultative forms. In this group we find the connecting links between the characteristically putrefactive and the characteristically fermentative types.

Turning now to the fermentation of foods of plant origin, and especially those rich in starch and sugar, we find a large number of so-called species which may be more or less active. Since the general tendency in this type of fermentation is to produce acids, only those species which can endure considerable acidities will long persist, the others gradually being eliminated as the growth conditions become unfavorable. Here, too, should be mentioned more emphatically the action of sugars in restraining putrefactive change, a phenomenon which has the effect of still further checking the development of the true putrefactive organisms of the first group. Notwithstanding this, the organisms involved in the fermentation of carbohydrates are in certain instances of the same species as those found among the putrefactive groups. This is particularly the case with the second group mentioned above. Bacillus coli and Bacillus aërogenes and their various relatives, the enormously large group of the lactic acid organisms, both aërobic and anaërobic, and many cocci belong to this class. Of the greatest importance here, however, are the lactic acid producing organisms. As regards oxygen, many of these are facultative in character, and they are also capable of growing at either high or moderately low temperatures (ranging from above 50°C. to 0°C.), and give rise to lactic acid alone or to mixtures of lactic, acetic, formic and other acids either with or without gas formation. The character of the substratum determines to some extent the amount of decomposition which may thus take place. By their acidity, substances rich in sugars and starches undergo marked acid fermentation with suitable physical conditions, concentration, temperature, etc., and become not only disagreeable and sour to the taste, but may frequently contain quite high percentages of lactic acid. The rapidity of their action is sometimes startling, a few hours at a favorable temperature sufficing to permit extraordinary chemical changes.

Two distinct types of lactic acid organisms may be recognized, each of which may be markedly destructive to foods; first, those in which the sugar is split directly into lactic acid with no gas formation, as, for example, the true Bacillus acidi lactici group. Second, those in which gaseous products are found as well as the acids, as in the colon and lactis aërogenes group. In this class of carbohydrate fermenting organisms must also be included the butyric acid group which ferments starches and sugars into butyric and acetic acids with the formation of various gaseous products at the same time. This group works for most part anaërobically and consists of a number of different organisms varying slightly in general character but for the most part spore-forming, and capable of developing only within rather limited temperature conditions. Here also should be considered the organisms causative of the rotting of vegetables, mostly of the pseudomonas group. The yeasts and moulds capable of producing alcoholic and allied fermentation also belong in this division.

It has been impossible in the scope of this paper to describe in detail all the organisms which are known to play an important part in food decomposition. The above brief characterization may suffice, however, to show how numerous they are and how manifold is the action which they may induce. Of fundamental importance, when considered from the standpoint of food preservation, is the fact that in spite of their great individual differences in behavior and chemical activity, they all respond to the general law which is observed with all living things in relation to extreme heat and extreme cold. Whether spore-forming or not, short periods of heating at temperatures of 120° C. suffice to destroy all the cells, and continued exposure at temperatures of 0° C. or below suffices to inhibit almost completely all these organisms. This inhibition is, of course, but temporary in many instances, enduring merely as long as the organisms are exposed to the low temperature. When the food substance infected with these organisms is again brought to ordinary temperatures the organisms again spring into activity and begin their destructive chemical work.

THE BACTERIOLOGICAL EXAMINATION OF FOODS WITH SPECIAL REFERENCE TO GELATINE.

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THE BACTERIOLOGICAL EXAMINATION OF FOODS WITH SPECIAL REFERENCE TO GELATINE.

S. C. Prescott and C. A. Magoon.

Read before the Laboratory Section, American Public Health Association, Washington, D. C., September, 1912.

The examination of food substances may be carried on from two standpoints, first, to determine if adulteration has been effected, or if the food presents a normal tissue or cellular appearance and the proper percentage of the ingredients entering into its composition; second, to determine if it is in a condition such that it is wholesome, undecomposed, and free from organisms which may either be harmful in themselves or may cause putrefactive or fermentative change of such a nature as to impair the food value of the substance if development takes place.

Chemical and microscopical methods of examining foods for adulterating substances and for normal appearance have been in use for many years and have reached a high degree of accuracy in many instances. Unless decomposition is well advanced, however, chemical examination fails to reveal the changes induced by microörganisms and hence this method of investigation fails to be of great service in determining the early stage of putrefactive or fermentative decomposition.

For many food substances bacteriological examination offers a means of determining the true character of the food with greater certainty than does the chemical analysis. For example, chemical analysis will show if a sample of milk or butter contains the legal requirements of fat, or an excess of water or the presence of preservatives. It fails, however, to indicate the presence of undesirable types of bacteria, knowledge of which is of far greater importance from the standpoint of health than is the percentage of fat, and the finding of which in large numbers is in itself evidence of the absence or negative action of preservatives. While fully recognizing that the chemical methods of food examination are most necessary and always desirable, we wish to point out that bacteriology may supplement chemistry in a most useful way, and may frequently supply the chief really important facts relative to the fitness of substances for foods, as, for example, the bacteriological examination of oysters. Likewise, valuable results may be obtained in the examination of sausage, cheese, canned goods, meats, and many other food substances in which it is suspected that undesirable changes are being effected, providing knowledge of the normal condition of these foods is available as a sort of a base line for comparison, from which reasonable and safe deductions may be made. In canned goods, for example, the mere presence of bacteria is indicative of imperfect preparation and sterilization.

Among the substances used for food, in which bacteriological examination is of importance, gelatine occupies at present a conspicuous position. Although actually low in nutritive value, this substance, by much advertising and because of its adaptability to various culinary uses, has advanced from a mild adhesive and now occupies a position as a commodity in very general use. Notwithstanding this, or rather because of this widespread use, its manufacture from bones, pieces of skin, trimmings from hides, etc., makes it of special importance that we may be certain that objectionable organisms associated with the animal body, such as B. tetanus, B. coli, etc., are eliminated. Bacteriological examination of gelatine therefore becomes a necessity to the manufacturer, who wishes to maintain a high grade product, and to the food inspector whose duty it is to safeguard the public. Owing to the ease with which many bacteria decompose gelatine, it is also of importance to the manufacturer to know whether his product will stand intact under all conditions met in commercial practice.

The bacteriological examination therefore may be carried out from two apparent standpoints. First, the health standpoint; second, the commercial standpoint. In reality the aim in both cases is the same, namely, to determine if the gelatine is low in numbers and free from objectionable types of bacteria.

Owing to the prevailing methods of gelatine manufacture,—methods which are in a measure controlled by the physical properties of the product, it is almost or quite impossible to obtain gelatine in a germ-free condition without resorting to the use of strongly germicidal substances. We cannot, therefore, assume that a pure gelatine is one which is germ-free or vice versa, that a germ-free one is necessarily pure.

THE MANUFACTURE OF GELATINE.

Edible gelatines are made from trimmings from hides, bones, either raw or treated, dentelles, horn piths, etc. In America much of this material is imported and is of such a character that it may be more or less infected with bacteria of various types, including B. tetani.

This material is subjected to a long continued liming treatment after which it is thoroughly washed, the excess of lime removed by acid and again washed. The material is then ready for the boiling kettles where, by treatment with steam, the ossein or collagen is hydrolized into gelatine which is dissolved. Care is taken to avoid excessive or too long continued heat. After the removal of the gelatine thus extracted the process is repeated at a slightly higher temperature. The highest grades of gelatine are the ones best for food purposes and are obtained in the first run or boiling, although gelatine from the second treatment is also used for food purposes. Mixtures of gelatine from different sources are made by some manufacturers in order to obtain a fairly uniform product. The extracted material is then strained and goes at once to the evaporator where it is concentrated under reduced pressure until of approximately 10 to 12 per cent. solution. After thorough mixing and filtration it is cooled either by surrounding by cold water or by refrigeration after which it is cut into sheets and dried.

POSSIBILITY OF INFECTION IN PROCESS.

The early stages in the preparation of gelatine are essentially germicidal in character. The lime destroys many bacteria resident upon the raw materials and the acid treatment continues their destruction. Survivors of spore-forming types succumb almost completely in the boiling kettle, so that the product at this stage of the process may be regarded as practically sterile. After the concentration, however, infection may take place if the gelatine is subjected to unclean apparatus, dirty methods of handling and contamination from water or air. Thus a dirty unsterile filter may seed the gelatine with bacteria, or the use of distributing pipes not steamed out constantly with live steam may supply the first portion of a batch with innumerable bacteria while the last portion would pass through practically unaffected. Similarly, handling in the cooling and the cutting rooms may add its quota of organisms.

THE EFFECT OF TIME.

Even in gelatine which has been carefully prepared and reaches the cooling room with a very low bacterial content, or nearly sterile, the process of cooling to the proper solidity is likewise a process of incubation. In passing from the high temperatures to the lower ones the mass of material requires a considerable time so that it may be, and generally is, held for several hours at a temperature favorable for bacterial development. The result is that from this time until the drying has brought the concentration to an inhibitive point the germs are increasing more or less rapidly in the medium, and their number is being augmented by infections from the air and from the hands of workmen. In view of all these possibilities, therefore, it is to be expected that gelatine which is itself so easily utilized as food for microörganisms should contain considerable numbers of bacteria and a more or less varied flora.

METHODS OF EXAMINATION.

In the work which has been used as the basis of this paper both quantitative and qualitative results were obtained. A study of the problems involved led to the conclusion that the most reliable quantitative figures were those obtained by growing on standard agar at 37 degrees C. with an incubation period of two days. Anaërobic methods were found to add nothing of value in this respect. For inspection purposes and to maintain this work in line with that done on other foods, milk, oysters, etc., determinations of the approximate numbers of gas-forming types have also been made, dextrose broth and lactose bile being used for this purpose. For all this work the standard amount of material taken was one cubic centimeter of the melted jelly in the investigation of the different steps of manufacture. In the examination of the finished product results were based on the gram weight of material, but for greater accuracy in work, solutions were made using five-gram samples and dilutions from these prepared. At the outset it will be found that samples even from the same lot or batch will give great variations, hence the necessity for care in sampling and for thorough mixing.

QUANTITATIVE RESULTS.

A large number of determinations of bacteria in different samples of gelatin have been made, the results of which need not now be given in detail. Here it will suffice to show the approximate number of bacteria found at different stages in the manufacturing process:

From the kettles,	10 to 500 per cc.
From the filters,	5 to 50 per cc.
Hose at cooling room,	5 to 100 per cc.
From solidified gelatin,	1000 to 100,000 per cc.
Green sheets after cutting,	2000 to 200,000 per cc.
From dry sheets,	Numbers very variable, depending upon conditions, ranging from a few thousands to many millions in exceptional cases.

GENERAL CONCLUSIONS.

From the standpoint of gas production in lactose bile and dextrose broth it is worthy to note that the fermenting or gas-forming types of organisms are almost always present in small numbers even in the early stages of the process. Compared with the total numbers of bacteria found they are in general very few. Even in the materials directly from the kettles they may be found indicating that they are resistant to heat if not actually spore-forming. The occurrence of these fermenting types suggests the presence of organisms of the colon type, indeed there has been a tendency to call such organisms "colon bacilli" and to regard them as indicative of pollution. On this point we have concentrated a great deal of attention and have come to the conclusion that true colon bacilli, while frequently present, are not *constantly* present in large numbers, at least they do not occupy a more prominent position than some other types. As a result of the detailed study of about seventy-five cultures we have classified the bacteria found in four groups.

Group I. In the first group may be placed organisms giving all the usual colon reactions, showing from 30 to 75 per cent. gas in lactose bile and from 25 to 100 per cent. gas in dextrose broth. Both communior and communis types were isolated and are here grouped together.

Group II. This we regard as the most characteristic group of gas-forming bacteria occurring in gelatin. The organisms of this group grow vigorously on all media, simulate colon bacilli in the growth of agar but liquefy gelatin, fail to reduce nitrates to ammonia and fail to produce indol. The gelatin liquefaction is very rapid, frequently taking place within twenty-four hours, considerable variation is noted in the production of nitrites, motility and growth on potato.

Group III. This group consists of bacilli which liquefy gelatin, form spores, produce no gas in dextrose broth, lactose broth or lactose bile but produce acid in milk, reduce nitrates and give a positive indol test.

Group IV. Here are included all the coccus forms found, for the most part staphylococcus. These produce no gas, but do form indol, reduce nitrates, give acid in milk and generally liquefy gelatin. These are frequently very numerous and may even be the predominate types so far as actual numbers are concerned.

This grouping of the organisms found is subject to revision, and further work is in progress, especially in the hope of clearing up the doubt which may now exist in regard to the gas-forming species.

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THE LIMITATIONS OF THE PHENOL COEFFICIENT IN THE STANDARDIZATION OF DISINFECTANTS.

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A disinfectant may be tested by the determination either of its absolute germicidal effectiveness under stated conditions, or of its relative effectiveness with respect to some other disinfectant. The one method gives its absolute germicidal power, the other its relative power or germicidal coefficient with respect to the other disinfectant. The phenol or carbolic coefficient, due to Rideal and Walker is the best known example of the latter method and the term standardization of disinfectants has come to mean the comparison of the strength of any disinfectant with that of phenol under certain standard conditions.

If such phenol coefficients exist, their determination, for a series of disinfectants, would be of greatest commercial and economic value. Unfortunately there is abundant evidence that no such constant relation between the efficiencies of any two disinfectants is determinable. The absolute germicidal power of a diluted disinfectant depends, for example, upon the concentration, that is, the amount of disinfectant in the solution, but it is seldom directly proportional to the concentration. The efficiency of one germicide may vary directly as the concentration of another as the sixth power of the concentration. Obviously then, there can exist no "coefficient" which will state the relative values of these two. Doubling the amount of the disinfectant will double the efficiency of the one and increase that of the other by 64 changing the ratio or coefficient 32-fold. This, it is true, is an exceptional case in that disinfectants of widely differing types are represented—mercuric chloride and phenol—but that such extreme discrepancies are not noted in every-day practice is due wholly to the fact that our investigations are concerned largely with coal tar distillates of very similar chemical properties.

There are numerous other factors, such as temperature, time of contact, etc., which affect the actual germicidal powers of any two disinfectants disproportionately. Consequently if these be varied, the "coefficient" or relative value necessarily varies. The effect of concentration cited will serve as an example of the indeterminate character of the phenol coefficient or of any other similar ratio. In general, the germicidal powers of two disinfectants, although affected by varying physical conditions, are not similarly affected, so that varying conditions give a varying ratio of these two germicidal powers, or, in other words, a varying coefficient.

It is interesting now to see what cognizance is taken of these matters in the Rideal-Walker coefficient as determined by the various methods that have been proposed. The first essential in a "coefficient" is that it shall be constant for a given pair of disinfectants, and the fact that the ratio between the efficiencies of two germicides under varying degrees of concentration, temperature, etc., necessarily varies, might appear to be a serious bar to the determination of such a coefficient. Such was found to be the case and it has become necessary to limit these physical conditions one by one as each new variable has asserted itself. The latest result is the most excellent technique recently reported by Anderson and McClintock. This leaves little to be desired in the matter of refinement and control, and if phenol coefficients are to be determined, one most heartily endorses some such method. All variables are carefully eliminated even down to the test organism,—not only the kind of organism but the lineage of the strain being specified.

But suppose, in actual practice, germicides should be used on ordinary typhoid germs, not of the Hopkins ancestry, or even upon tubercle bacilli, on car floors. In general, suppose the practical conditions are in any way or in many ways unlike those under which the test is made. In attempting to fix the non-existent "phenol coefficient" by the successive elimination of variables, have we not lost sight of the primary reason for all this work, the valuation of disinfectants?

For answer let us define a phenol coefficient. In their excellent paper upon the Standardization of Disinfectants,[1] Anderson and McClintic do not define the coefficient in so many words, but in their discussion of cost and valuation, it is implied that a disinfectant with a coefficient of two is twice as valuable as phenol, i. e. may properly command twice the price. Conversely, at the same price, the cost of the disinfectant per unit of efficiency is one half that of phenol. One is justified then in regarding the Hygienic Laboratory phenol coefficient as the relative efficiency of the disinfectant in question compared with phenol. The same definition might apply equally well to the Rideal coefficient, yet the two coefficients may vary widely. Is this then a fair definition of the result of the specific test by which the coefficient was determined? Obviously it is not. A coefficient must bear all the restrictions that have been imposed. Under the exact conditions prescribed, starting with the Hopkins typhoid cultures 24 hours old, in extract broth, previously transplanted on three successive days by carrying over each day one loopful of a 4 mm. platinum loop to the final observation of the weakest dilutions which kill in 2½ and fifteen minutes respectively; every move is carefully planned to protect the test against just those variables that ought to be encountered and determined.

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[1] Pub. Health and Marine Hospital Service Hyg. Lab., Bull. 82, 1912.

A coefficient is eventually obtained and with sufficient care may be duplicated, even by other workers, but the manner of its birth must not be forgotten. It is not the relative efficiency in general terms. It is the relative efficiency under one of the thousands of possible combinations of all the variables, namely, the particular conditions imposed by the technique of the test. With other techniques, equally worthy of adoption, widely differing values would result, all having equal claim to recognition.

Surely no fundamental significance can attach to these phenol coefficients when an entirely new series of values would result from the adoption of:

(a) Another strain of typhoid organism or even the same strain grown under other conditions;

(b) The use of more or less of the culture in the test, or its equivalent, the use of a culture not twenty-four hours old;

(c) The adoption of another standard time for the duration of the test.

Anderson and McClintic give an interesting example of the last named point. They determined coefficients at 2½ and 15 minutes. The latter is at times twice the former; in one quarter of the cases it is over 50 per cent. greater; and in all the 81 cases it averages 32 per cent. greater. By the Hygienic Laboratory coefficients, with organic matter, trikresol (2.50) is more efficient than sulpho-naphthol (2.33) in the ratio of 1.07; with the three minute coefficient the ratio becomes 1.25, while with the 15 minute coefficient, the superiority is reversed in favor of sulpho-naphthol in the ratio 1.11; a total difference of 36 per cent. in the comparative valuation of these two disinfectants. One of the most powerful disinfectants reported gave a value of 7.50 at 2½ minutes and 12.22 at 15 minutes. Manufacturers might seriously and very properly object to the arbitrary selection of any particular time factor under these circumstances.

The authors themselves show that a variation of 33 per cent. is possible if the selection of the time factor be left to the bias of the operator. No good reason, however, appears for the arbitrary selection of any standard time of testing and the recorded facts show clearly that the resulting coefficient is quite dependent upon the particular time selected. With some disinfectants, the influence of time is slight or nil, with others it is great. Hence varying times affect the final coefficient of two disinfectants differently, and one or the other may have the greater "phenol coefficient" according to the time actually adopted as standard.

Unfortunately the conditions of practice may be quite remote from the standard conditions of the test and the true relative values under the natural conditions of use may be equally remote from the phenol coefficient as determined. In the cases just illustrated, one would ordinarily give more weight to the 15 minute coefficient than to the 2½ minute value or to the average.

The limitation of the phenol coefficient is nowhere more plainly shown than where it is applied in practice. The most obvious application of a coefficient lies in determining relative costs of disinfectants. At the same price per gallon, a disinfectant with a coefficient of two costs half as much per unit of disinfecting power as phenol or another disinfectant, having a coefficient of one. If the coefficient be two, under specific conditions of concentration, temperature, time of contact, etc., and may become one under other specific conditions, then relative costs vary to the same extent. If the coefficient be two for typhoid bacilli, it may be only one for pus organism; a second disinfectant may have a reverse relationship. Grave injustice would be done by assigning costs to these two based on typhoid tests if in practice the cocci were the organisms to be destroyed.

Whatever then may be our attitude on the value of testing disinfectants, one must strongly protest against the application of this highly specialized "coefficient" for the determination of the cost of disinfectants per unit of disinfecting power, that is, their valuation.

The carbolic coefficient of Rideal with its varied modifications is now so well known and so generally used, and represents such an important step foreward, that one might hesitate to oppose its use in the absence of any alternative.

The writer has published elsewhere[1] a contribution to this subject in which the more fundamental theoretical and bio-chemical aspects of the problem are discussed. Instead of eliminating variables, the more important of them which had any theoretical basis were included in the study. As a result, three factors were evolved which relate to the absolute, not relative, efficiency of the germicide under a wide range of conditions.

These covered the more important physical and chemical conditions of practice and by them a given disinfectant is rather fully defined as to its action under all variations in these conditions. This study is a part of a purely theoretical investigation in chemical biology and its application to the practical problem of testing disinfectants is only incidental. The certainty with which it demonstrated the non-existence of a single phenol coefficient (as well as of a thermal death point and many other sacred concepts of bacteriology) seemed to justify an attempt to apply it to this problem. It is difficult to understand in principle and requires further development in technique. Giving three or more final terms of comparison, it does not permit generalized cost efficiency calculations or even facilitate comparative valuation of two disinfectants. On the other hand for known conditions of practical application these three or more factors indicate clearly the relative efficiencies of a series of disinfectants.

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[1] Journ. Inf. Dis. 8, 1911, 27.

In conclusion the writer wishes to express his great admiration of and respect for the work of Rideal and Walker, Anderson and McClintic and others in this field. They have gradually brought the technique of this difficult test to a high degree of perfection. Until the refinement of practice necessitates a more complete and less arbitrary method of comparison the phenol coefficient will undoubtedly be widely used. With a full knowledge of its limitations and of the fundamental facts which underlie them, it can be used to much good purpose. It is only with an earnest desire to place these limitations upon the record that this contribution to an important subject is submitted.

Sanitary Research Laboratory. Mass. Inst. Tech.

MILWAUKEE
BUREAU OF ECONOMY AND EFFICIENCY

Created by Common Council
For the Investigation of Departmental Accounts and Methods
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BULLETIN NO. 15

HEALTH DEPARTMENT
2. EDUCATION AND PUBLICATIONS

BY
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LETTER OF TRANSMISSAL

CITY OF MILWAUKEE
BUREAU OF ECONOMY AND EFFICIENCY.

Dr. F. A. Kraft,
Commissioner of Health,
Milwaukee. September 6, 1911.

Dear Sir:

We submit herewith the report of the Bureau of Economy and Efficiency on the Division of Education and Publications of the Health Department, prepared in co-operation with the chief of this new division, Fred W. Luening.

This report has been prepared especially for the purpose of emphasizing the tremendous importance of the educational and co-operative work to be accomplished by the Health Department through its new division.

It seems that there is nothing so vital as this kind of endeavor, and it is necessary that all organizations which are working to bring about a healthier, happier and more improved community, as well as the general public, should be acquainted with the aims of the Health Department.

Too long has the Health Department been regarded as an office of mere restrictive routine of a police character. Now, with the stimulus of the teachings of modern bacteriology, and the scientific study of epidemics and of the modes of transmission of communicable diseases, the Health Department has acquired weapons which enable it to carry on active, aggressive and fruitful campaigns for the bettering and saving of human life.

It is becoming more and more evident to all thinking sanitarians that such campaigns can only reach their maximum efficiency through the education of the public and its intelligent co-operation.

It is recommended that consideration be given the measures suggested for bringing about such efficiency.

Respectfully submitted,

(Signed) J. R. COMMONS, Director.
(Signed) B. M. RASTALL, Director.
(Signed) L. S. EVERTS, Director.

THE DIVISION OF EDUCATION AND PUBLICATIONS

INTRODUCTION

The Common Council of the City of Milwaukee recently passed an ordinance creating a new division of the Health Department to be known as the Division of Education and Publications. It seemed advisable to the Bureau of Economy and Efficiency and the Health Department that a report should be jointly prepared which should outline the functions and duties of this new division. It is the purpose of this report to indicate what the possibilities and responsibilities of the new division are, so that they may constantly be borne in mind and represent a definite goal to be ultimately reached.

The ordinance allows the appointment of a chief and an assistant chief for the division. The chief is directly responsible to the Commissioner of Health, and his assistant, who will act in a large measure as secretary and stenographer, is under the direction of the chief.

General Purposes of the Division.

The inauguration of this division marks another forward step on the part of the health authorities, and one of special significance. Many health departments have beeen conducting educational campaigns during the last few years, but to the knowledge of the bureau no department in the United States has prior to this established a separate and distinct division to have charge of this vital work.

It is realized by progressive sanitary authorities that they cannot hope to secure the best results, however efficiently they may do their work, unless they have the good will and cooperation of the people. Co-operation in the past has been far from thorough or complete; indeed, opposition has been frequently encountered by health departments in their efforts to curb the spread of disease and in their endeavors to eliminate conditions capable of bringing about a low vital resistance. The maintenance of a high vital resistance is essential if preventable disease is to be kept at a minimum. The battle against disease is a hard one, but the proper armor for such a fight can be obtained in most instances, although as a rule the combatants are ignorant of this fact. It is one of the chief purposes of this new division to teach the people how such armor against disease can be made and obtained.

The relation of disease to economic and social conditions is enormous and far reaching. The size of the family income; the nature of employment; the conditions in the workshops and factories; the price of food and clothing; housing and other environmental conditions, all have an important bearing on the health of the people. If the knotty problems which lead to the horrors of poverty and crime, to an immense amount of sickness, and to a terrible waste of life, are to be solved by the operation of the proper remedial agencies, it is essential that there be a thorough understanding and appreciation by those who are responsible for the existing conditions.

Good legislation serves a distinct and important purpose in the advancement of the human race, but unless it is accompanied by education, the best results are not possible of attainment.

The health department of a community is, or should be, a social agency and not merely a police department working entirely through prescribed laws and ordinances. It should have a broad educational function and should spread the gospel of sanitary living by proper educational and publicity methods. It should co-operate with all city or private organizations that are working directly towards the improvement of social or health conditions, and should likewise co-operate with and educate all individuals engaged in any pursuit which has any bearing on the public health. This kind of work is of supreme importance and the new Division of Education and Publications is planned to serve the community in this unique manner.

The Hon. Eugene H. Porter, State Commissioner of Health for New York, recently pointed out that "sanitation with all its wealth of scientific achievement, with all its earnest and able workers would never have made such rapid advance without the aid of an aroused and partially emancipated public sentiment. When many men thinking independently come to the same conclusion action is likely to follow, and when men so thinking demand facts and carefully weigh the evidence there is likely to be action along right lines. Education is the dynamite of our civilization. It has broken some of the follies of superstition and ignorance and will break many more."

Co-operation, as one of the chief functions of the division is understood, although it does not appear in its title. One of the strongest and most valuable functions of this division is the development of co-operation with the State Board of Health, the numerous social agencies in the community, the city departments doing work of some sanitary significance and the medical profession. The need for a better knowledge of what others are striving to attain, what their ideals are and how they are going about their work, is apparent. There is a great cry for efficiency in these days, and if efficiency is to be attained in social and health work, there must be a closer co-ordination of the efforts of the different societies working for these objects. The time is not far distant when health departments will employ social secretaries on their regular staff who shall act in a manner somewhat similar to those employed by some of the progressive hospitals.

The work as planned is not as complicated as the chart might lead one to believe. The contact with many of the departments or societies would in most cases be only occasional, but at that they might be very important. For example, in the case of the Building Inspection Department, it might be necessary to suggest certain changes or amendments in the building ordinances from the health point of view. The need for co-operation at that time would be vital.

GENERAL PLAN OF WORK

This report is not meant to be a detailed one. Its purpose is to give a comprehensive idea of the work proposed, and the general program to be followed. Details will have to be worked out as time goes on and as the division grows in importance in the community.

The accompanying chart is designed to show diagrammatically the opportunities for educational and co-operative effort that are available to the division. It is hoped that it may emphasize the wonderful possibilities of scientific co-operation and the enormous ramifications of which it is capable.

Education and co-operation are shown separately and are connected with the various organizations and agencies according as the nature of the work of the division may be considered co-operative, educational, or both.

It is apparent that general co-operation should be obtained from all. This is understood, but in the diagram the co-operation indicated is administrative in nature, and represents co-operation with organizations.

The work of education may be direct or indirect. It is "direct" in all instances when the division itself does the actual educational work, and "indirect" in cases when other agencies which are in a position to do such work become active as the result of the co-operation and stimulation of the division.

The methods by which education may be accomplished are shown on the diagram above the circle that represents the educational function of the division.

It is recognized that much has been omitted from the chart and that the placing of some of the organizations under the various headings might be open to question. It must be remembered, however, that these are small points and that the real purpose of the chart is to emphasize the opportunity and necessity for scientific co-operation and the advancement of education through all possible channels.

The remainder of this report is a short consideration of the channels through which the activities of the division will be carried on and through which education and co-operation will be accomplished. It will necessarily be a gradual process before the division can work up to its greatest efficiency. More money will have to be appropriated for the purposes of the division, if the ideal is to be approached.

MUNICIPAL DEPARTMENTS

HEALTH

Health Department. Instruction of Staff.

Recognizing that the majority of the employes of the Health Department are not technically trained men and do not have the scientific knowledge that is necessary for the most effective conduct of their work, it is proposed that education should be begun within the department. Inspectors in those divisions dealing with contagious disease, sanitary inspection (including factory inspection), and milk and food inspection should have special courses of instruction arranged for them. These courses should include a study of: (1) details of work and the reasons for the various requirements, (2) health ordinances, and (3) the relations of the inspector to the people with whom he is brought into contact in his official capacity.

In all but the largest cities, where the staff is so numerous that inspectors of one division do not have to perform any of the duties of another, it is necessary that an inspector should have a general knowledge of the work of all divisions, as well as special knowledge of the division to which he is primarily connected. In such a case, inspectors may be transferred to work of pressing character without fear of their being incapable of handling it efficiently, when occasion arises.

At the present time in Milwaukee the Health Commissioner is giving instruction to the inspection staff. It is proposed to reorganize this work, make it more complete and thorough, and to have the chief of this new division responsible for arranging the courses. The courses to be given will not be very lengthy or complicated. Much of the instruction will be given by the Health Commissioner and the heads of the different divisions. As opportunity serves experts in various branches of sanitary science might come and give special lectures on timely subjects.

Co-operation. The importance of co-operation within the department needs no argument. The chief of this division should make it his business to see that harmony prevails and that friction is eliminated. Cases of friction that present peculiar difficulties should be reported to the commissioner for action.

Tuberculosis Commission. This commission is chiefly an educational and publicity commission, and therefore its chief function is to interest the public of Milwaukee in the tuberculosis problem. From four to five hundred people die every year in this city from tuberculosis. Prevention is difficult because this disease is an economic one. The final solution of the problem will come only with the solution of the economic problems which produce it.

If four or five hundred people should die in a year in Milwaukee from the bubonic plague, there would be a tremendous outcry. Vast sums of money would be spent to eradicate the disease, and the effort would probably be successful. But the white plague, which carries off so many people year after year, fails to arouse on the part of the people and the authorities the necessary interest. Although the prevalence of the disease and the methods that should be used to control it have received some publicity, no vigorous assault has been made against it, as would have been made against the bubonic plague.

With the appointment of the Tuberculosis Commission and the increasing enlightenment of the public, the time is peculiarly ripe for a vigorous campaign. The campaign against this disease must necessarily be a protracted one. There should be constant co-operation between the Tuberculosis Commission and this division.

Child Welfare Commission. The Child Welfare Commission is doing some intensive work in a selected section of the city on the prevention of infant mortality. An attempt is being made to install every condition favorable to infant life. The purpose of this investigation is to ascertain just how much of a decrease in the infant mortality of the district can be obtained through the concentration of all remedial agencies. The Health Department should be actively interested and should co-operate with the commission, both in making special investigations in the field and in preparing educational material for distribution to mothers. The infant mortality of a district constitutes an index of its general sanitary status inasmuch as all insanitary conditions have a particularly harmful effect on young children. Milk supply, housing, general cleanliness and other environmental conditions are all directly connected with the problem of infant mortality.

Special efforts should be made to co-operate with the Child Welfare Commission in the vital work of educating mothers in the care of their children. The Health Department should be doing for the whole city what the Child Welfare Commission must necessarily do in a restricted area, with the ultimate object in view that every mother in the city who needs assistance, either educational or otherwise, may be reached.

The fight for the prevention of infant mortality has only begun. The opportunities are tremendous both in the elimination of sickness and in the saving of lives.

PUBLIC SERVICE

Public Works Department.

The garbage disposal of a city has some sanitary significance, and in many places is in the hands of the Health Department. It belongs more properly to the Public Works Department. However, on account of its sanitary significance, it should never be lost sight of by the Health Department. Garbage disposal is only one of the functions of the Public Works Department that involves the problem of sanitation.

Much more important, from the standpoint of public health, is the care of the city water. Water is a frequent vehicle of disease germs, notably of typhoid fever. Where a sporadically polluted water is drunk without purification, as in the case in Milwaukee, there is always danger. The Health Department should be insistent in its demand that the water be rendered permanently safe by suitable purification. Co-operation with the Public Works Department should be maintained at all times so that in periods of danger no hitch may occur in the effort to properly safeguard the people against typhoid fever and the other preventable water-borne diseases.

Police Department.

If the plan embodied in the special report concerning "The Transfer of a Certain Part of Sanitary Inspection From the Health Department to the Police Department" becomes operative, the closest co-operation between the Health and Police Departments will have to be maintained. Even under present conditions, such active co-operation should be encouraged. A proper enforcement of the anti-spitting ordinance, for example, is impossible unless the Police Department assist in carrying out its provisions. The necessity of police guard for quarantined premises at special times further emphasizes the need of some arrangement that will bring about close co-operation.

The Police Department can be of considerable assistance to the Health Department in controlling tuberculosis, if it will order its patrolmen to keep note of cases occurring on their beats. It has been recommended that the Health Department supply the Police Department with lists of persons ill with tuberculosis, together with their addresses and the police districts in which they are situated. The police officer is to note upon the list whether the cases given are at the stated address, and if not to find out, if possible, the addresses to which they have removed.

Department of Building Inspection.

The close relationship of bad housing to disease needs no explanation here. The Health Department is vitally concerned in the building regulations, both of the city and the state. Such co-operation would be particularly necessary at times when modifications or additions were being made in the building code, in order that the sanitary aspect of the problem might receive proper attention.

The state tenement-house law depends for its enforcement in the city upon the Department of Building Inspection and the Department of Health. There must be close co-operation between these two in order that they may not neutralize their efforts by working at cross purposes.

EDUCATION

Public Library and Museum.

The Public Library can be stimulated to place upon its shelves the standard works dealing with personal and public hygiene, and to distribute lists of such books. The Library should be encouraged to subscribe for the leading magazines on sanitary science.

The Natural History Museum of New York City has recently created a Division of Public Health. This division is preparing an exhibit of all kinds of sanitary appliances and water purification plants. The manner in which disease is spread is shown by suitable models and charts. The educational value of such an exhibit is very great, and it is suggested that the Public Museum here might consider the advisability of maintaining some exhibits of this character.

Municipal Reference Library.

This library can be used by the chief of the division as a special reference library for annual and other reports of health departments. Among the librarian's duties is the investigation of any matter referred to him; he would be of direct service to the division in looking up questions of sanitary procedure elsewhere. Statistical bulletins and reports which the library issues should also be of educational value.

School Board.

The opportunities for co-operation with the School Board are many and represent one of the most essential duties of the Division of Education and Publications.

There is no easier nor more direct way of improving the health of a community than by proper education of the coming generation in the laws of hygiene and the principles of the public health. Much criticism has been directed in the past throughout the country against the methods used in teaching hygiene in public schools and also against the character of the material in the text books used. There is no doubt that much of the criticism has been well founded, and progressive educators are beginning to recognize the deficiencies of the past and to introduce practical courses. There should be co-operation between the public health and the school authorities in working out the curriculum of study proposed.

Most cases of preventable disease arise from a neglect or ignorance of the simple laws of personal hygiene. The growing realization that disease is largely spread (1) by contact with patients, (2) by contact with unrecognized and atypical cases, and (3) by contact with persons who, although apparently well, yet harbor the microbes of communicable disease in their systems, emphasizes the absolute necessity of a proper knowledge of personal cleanliness on the part of the general public. Medical inspection of school children will never be sufficient to eradicate communicable diseases in the schools. It is not contended that the teaching of personal and public hygiene in a thorough manner will bring about this utopian state of affairs. It is, however, undeniable that by suitable educational methods much can be done to make the rising generation feel an increased responsibility as to what the individual should do to preserve his own health and to protect others from a risk of disease on his account. The gospel of clean living must be preached continuously and forcibly in the public schools.

There is a splendid opportunity for distribution of suitable educational health bulletins to school children. The children would act as distributing agents, taking the printed matter home, where the family might have an opportunity to read it and reap the benefits of the information contained therein.

Medical inspection of school children is in many places carried on by the Health Department. This is largely due to the fact that in the beginning the work was in connection with the detection and control of communicable diseases. As it has developed this has become only one part. More and more attention is being laid on the physical examination of children, and the condition of their eyes and teeth. Absolute co-operation between the medical inspectors and the Health Department should exist as far as communicable diseases are concerned. The school doctors should be kept in close touch with the contagious disease situation in the city, and especially in the district in which their work is done, in order that they may be on the lookout for mild, unrecognized and atypical cases, which so often start school outbreaks. They might also give special lectures to the teachers on the detection of disease in children. The importance of venereal disease is being now generally recognized and the great conspiracy of secrecy that has been maintained on this subject is at last beginning to show signs of being broken down. Among the most important reasons for the prevalence of venereal disease may be mentioned the lack of knowledge (1) of the terrible dangers of these diseases and (2) of the physiology of the sexual organs. Health departments have done almost nothing as yet to control gonnorrhea and syphilis.

The school is the proper place for instruction to be given in these important matters. The terrible slaughter of innocent mothers and babies that is now taking place will surely be decreased if the coming generation is properly informed of the grave dangers of immorality. With certain classes of people fear is a more powerful agent in bringing about results than moral teaching.

EDUCATIONAL, CIVIC, AND RELIGIOUS ORGANIZATIONS

EDUCATIONAL

Private and Parochial Schools. These schools are independent of the city government, but close co-operation with the Health Department is not less necessary. Most of them have no medical inspection. The Division of Education and Publications should endeavor to secure such inspection in order that this great instrument for public health may operate for all children in the city, irrespective of the schools which they attend. The general remarks made in connection with public schools are applicable to parochial and private schools.

University of Wisconsin. The University of Wisconsin has demonstrated its desire to assist the cities of the state. Its corps of experts in the various branches of sanitary science should be of great assistance to the Health Department.

It is also possible that arrangements might be made to have the University Extension offer courses of instruction in sanitary science, which could be taken by the inspectors of the department, and also by men who were desirous of entering the public health service and wished to suitably equip themselves.

Young People's Organizations. Under this heading are included the Y. M. C. A., Y. W. C. A., Young Men's Polish Association and many other organizations of educational and semi-religious character. The opportunity for direct educational work through these important organizations is a promising one and should not be overlooked.

State Tuberculosis Association. The State Tuberculosis Association is one of the leading organizations of its kind in the country, and does a great deal of educational work throughout the state. The co-operation of this organization would be valuable at times when lectures and exhibits were being arranged for; and it could give good advice on the best methods to be used in conducting educational campaigns on tuberculosis.

CIVIC

Civic Leagues and Other Civic Organizations.

Civic Leagues are naturally interested in the Health Department and its work. Their interest should be stimulated and their cooperation encouraged. They may be particularly useful in securing general cleanliness in the city, and in eliminating nuisances. They may also act as educational centers.

RELIGIOUS

Churches and Religious Associations.

Churches should serve as educational centers. The realization that cleanliness is not merely akin to Godliness but is rather an intrinsic part of Godliness, is forcing churches to take an increased interest in the health of their congregations, and of the general community. As a result, organizations connected with churches are taking a lively interest in health matters. This is as it should be, but further development is needed. Too frequently the activities of such organizations are limited to talking about unsatisfactory conditions.

Tuberculosis Sunday has become a great institution, and the idea is an admirable one. It might be possible to have more days set aside for consideration of other immediate phases of public health work.

MEDICAL AND SANITARY ORGANIZATIONS

MEDICAL PROFESSION AND MEDICAL SOCIETIES

The Health Department must have the proper co-operation of the medical profession if it is to make headway in the fight against disease. The medical profession has a high standing in the community and its opinions are usually accepted without hesitation. It may serve as the most valuable coadjutor of the Health Department, or as its most serious obstructionist. Necessary co-operation is not difficult to secure in most instances. It requires merely on the part of the Health Department a policy of mutual understanding.

Particularly in the reporting of contagious diseases is co-operation with the Health Department necessary. Physicians should be made to realize the importance of their services in reporting communicable diseases, rather than be clubbed into doing so by fear of a fine. Most of them are anxious to assist the health authorities in their attempts to stamp out communicable diseases. The small minority who cannot be reached by the ordinary methods should be vigorously brought to account.

In the reporting of births, also, the medical profession should be encouraged to co-operate with the Health Department. Not only are birth certificates valuable in protecting the rights of the individual, but when taken collectively, they form a very important basis for much health work. Unless births are properly recorded, it is impossible to obtain accurate information as to the birth rate, and the rate of infant mortality.

Dr. E. C. Levy, Health Officer of Richmond, Virginia, in a paper emphasizing the importance of co-operation of the medical profession in municipal health work, makes the following remark:

"To every conscientious man placed at the head of the health department of a great city there must come moments when he is appalled by the stupendousness of his task. At such times, but by no means then only, does he find his greatest encouragement in remembering the assistance which he can get from a sympathetic and well-informed medical profession. The doctors of a city constitute a force in public health matters far greater than they themselves realize, but, like all great forces, this must be intelligently applied; for, undirected, it may go to waste, or, exerted unwisely, it may constitute a veritable danger instead of a blessing."

It is also extremely advisable that the good-will of the County Medical Society and other organizations of physicians be obtained.

STATE BOARD OF HEALTH

The State Board of Health has authority over local boards of health in many respects. For example, it determines the minimum periods of quarantine, and local authorities can only enforce them. A city of Milwaukee's size should accordingly be in close touch with State authorities. The local Health Department should aid the State Board with suggestions regarding the addition of new regulations or the alteration of existing rules which have been proved defective. The State Board, in return, is ready to advise the local department whenever such counsel is desired. The chief of the Division of Education and Publications should be in close personal contact with the State Board. Co-operation will become more and more essential in the future, as the State Board is sure to grow in importance and to receive larger appropriations. The State Board will then perform more field work than at present, and there will be an increased need for co-operation in order that friction and duplication may be avoided. The two boards should be working in harmony and co-operation for the added reason that they may present their united strength in the State Legislature in securing desired legislation. Unfriendly feeling or indifference between the State and the local Health Departments is to be strenuously avoided.

PRIVATE DISPENSARIES AND VISITING NURSES ASSOCIATIONS

The private dispensaries in the city are largely concerned with tuberculosis. They maintain nurses who do home visiting and whose work is largely educational. Co-operation with these dispensaries has large possibilities. In the first place, they can serve as educational centers for the distribution of tuberculosis literature. In the second place, they are in a position to notify the Health Department of cases that come to their notice, and in this way improve the registration of tuberculosis. Finally, they can inform the Health Department of removals, which they would be in an excellent position to discover, and this would aid in having the disinfection of infected premises done by the Health Department.

The Visiting Nurses' Association is also in a position to assist the Health Department in its tuberculosis work. Until the Health Department has its own nurses for tuberculosis, it is going to be necessary that there be close co-operation between the private organizations that maintain nurses and the department.

OTHER SANITARY ORGANIZATIONS

The Marine Hospital and Public Health Service of the United States Government desire to assist local health authorities wherever necessary, and co-operation with them should be maintained.

Much can be learned by keeping in close touch with the boards of health of other cities and benefiting by their experiences.

The chief of this division should be a member of the American Public Health Association, and be sent as a representative of the Health Department to its annual meetings.

CHARITABLE ORGANIZATIONS

BUREAU OF ASSOCIATED CHARITIES AND HEBREW RELIEF ASSOCIATION

These two organizations are extremely interested in disease as related to the problem of poverty. They are probably in a better position than most organizations to realize the close relation between social conditions and preventable sickness. Their visits are limited to the poorest sections of the city, where they constantly find insanitary conditions which should be removed. Their co-operation is particularly important because they do inside work, and many conditions existing within the house are responsible for disease

Furthermore, sanitary inspectors on their rounds not infrequently discover cases of destitution, which they cannot alleviate, but which demand immediate attention. It would be a simple matter to notify one or the other of these organizations of such cases so that they could give the necessary aid, if there were close co-operation with the Health Department.

These two organizations are composed of prominent and public spirited citizens in the community, and if the Health Department were working in conjunction with them, it would undoubtedly find in return that its efforts would receive larger public support and encouragement.

What has been said above with regard to the Bureau of Associated Charities and the Hebrew Relief Association is true of other charitable organizations, and needs no further comment.

ORGANIZATIONS CONTROLING FOOD SUPPLIES

MILK AND DAIRY PRODUCTS

Bureau of Animal Industry Dairy Division.

The Dairy Division is willing to assist local health authorities in the improvement of the milk supply. It sends experts to instruct inspectors in the routine of inspection of dairies and to give other desired aid. Its advice is freely given to those who care to avail themselves of it. The Health Department should, therefore, keep in close touch with this division and make use of its services whenever practicable.

State Dairy and Food Commission.

There should be an opportunity for co-operation with this commission, but apparently it is not at the present time a very large one, as the commission devotes most of its time to butter and cheese. It might profitably include the inspection of dairy farms in its work, in which event it would be in a position to assist the local Health Department.

Milk Handlers' Association.

The various organizations of farmers, shippers and dealers can be of great assistance in improving the milk supply, if proper cooperation be secured. Special efforts should be made by the Division of Education and Publications to obtain the good-will of these organizations. As far as practicable, they should be consulted in connection with problems of the city milk supply and the methods of control used by the Health Department.

Farmers, Dealers, Carriers and Storekeepers.

The modern demand for pure milk must in a large measure find its solution in a greater realization, on the part of all persons who handle milk, of the vital necessity of sanitary precaution. Mere inspection, even if thorough and comprehensive, will not entirely solve the problem, because no system of inspection can ever be made sufficiently thorough to be a safeguard at all times and under all conditions.

The education of all those who handle milk can be accomplished largely through this division. Preparation and distribution of suitable educational literature, and arranging for meetings and conferences of those engaged in the industry are important methods through which the desired end can be attained. Incidentally, the various inspectors of the milk division should be trained to act not merely as inspectors, but also as instructors.

MEAT AND MEAT PRODUCTS

Bureau of Animal Industry Meat Division.

The Federal Bureau of Animal Industry maintains inspectors in the various stock yards in the city. At the present time there is good co-operation existing between this bureau and the Division of Meat and Food Inspection. This should be carefully maintained.

Butchers and Packers.

While meat cannot be considered as important as milk, yet it is sufficiently important to demand a certain amount of regulation. The same general educational methods employed in connection with the milk business should be employed also in the business of meat products.

OTHER FOODS

United States Department of Agriculture Chemistry Division.

There is considerable possibility of co-operation with the Chemistry Division of the United States Department of Agriculture. Its inspectors are constantly taking samples of foods in the city for analysis. At the present time, however, the Health Department has no way of informing itself concerning the activities of these inspectors. Some form of co-operation should be maintained which would not only be of value to the city but also to the Federal government. The city is at times unable to make necessary food examinations on account of lack of laboratory facilities. The United States authorities would undoubtedly be glad to render assistance.

Restaurant and Hotel Keepers and Other Persons Who Handle Food.

The Division of Education and Publications should make an effort, through proper literature, to improve the sanitary condition of the places where foods are handled. Modern sanitary science recognizes the grave danger of insanitary handling of foods in restaurants and hotels. Typhoid fever has frequently been traced to cooks and waiters. The danger is particularly great on account of the fact that contamination may come after the food has been cooked and when infection is no longer feared or guarded against.

INDUSTRIAL ORGANIZATIONS

STATE INDUSTRIAL COMMISSION

The recent appointment of an Industrial Commission with large powers in factory inspection offers an excellent opportunity for effective co-operation. The city maintains five factory inspectors, whose work must be carefully co-ordinated with that of the State Industrial Commission, if duplication of inspection and friction are to be avoided.

The Industrial Commission is also authorized to administer and enforce the laws relating to laundries, bakeries and stores. Here again there must be a co-ordination of work so that duplication may be avoided.

LABOR ORGANIZATIONS

Labor organizations have in recent years taken an increased interest in the problem of occupational diseases. They should be encouraged to pass rules with regard to the deportment of their members in the factory that might lessen the danger of contracting such diseases. Certain labor unions, for example, prohibit promiscuous spitting in the factory and punish offenders.

It is particularly desirable that the co-operation of the heads of labor organizations be obtained by the Health Department, if educational work is to be carried on. Experience elsewhere has shown that it is easy to secure such co-operation. In Germany special emphasis has been laid on the education of the working people on matters of sex hygiene and venereal diseases.

The opportunity for the distribution of educational matter presents itself in the factory. It is now becoming common in large industrial centers to have competent persons give short talks to factory employes at the noon hour on questions of personal and public hygiene.

FACTORY OWNERS

It is unnecessary to go at length into the importance of educating factory owners in factory hygiene, and securing their co-operation with the Health Department. It is well recognized that tuberculosis and other diseases are oftentimes manufactured along with the particular commodity of an industry. The factory owner should be approached personally in the effort to secure his co-operation. Education should come with the awakening of interest, and every encouragement given to the removal of insanitary conditions in the factory environment.

MERCHANTS AND MANUFACTURERS ASSOCIATION AND THE CITIZENS BUSINESS LEAGUE

These and similar organizations are largely interested in the health of the community. They have, as one of their functions, the advertising of the city as a desirable place in which to carry on industry and commerce. These organizations include in their membership all the largest employers of labor. The backing of these organizations should be obtained, as it would be a most valuable asset to the Health Department.

EDUCATIONAL AND PUBLICATIONAL METHODS

MONTHLY AND WEEKLY BULLETINS, CIRCULARS OF INFORMATION AND NEWSPAPERS

The major work of the division will be the preparation of the various publications of the department. By means of such publications, the division must seek to win the good-will of the public. In them lies the basic work of the division as the greater part of its educational efforts must be accomplished through publicity.

A monthly bulletin is now issued by the Health Department. It should be constantly developed and made more attractive, both in contents and makeup. Its scope and size should be developed as its mailing list increases, with the ultimate aim of reaching every householder in Milwaukee. It should contain not only educational information concerning methods through which disease may be prevented, but also the results of work done by the department. The names of dairy farms delivering milk into the city, and the percentage scores which they have received should be given. Suitable information with regard to the milk depots, restaurants, butcher shops and all other places where food is handled should be published. This method of publishing the findings of the Health Department, if properly done, would be the most important single factor in raising the general standard of cleanliness of these places.

This bulletin should also give an exact account of the communicable disease situation in the city. The Common Council should make generous appropriations for the upbuilding of this magazine. The magazine might be supplemented by a weekly bulletin in the future.

All circulars of information issued by the department should be prepared by this division. They should deal with specific subjects, for example: quarantine; the handling of milk and meat; regulations regarding restaurants and hotels; factory hygiene and the care of babies. When necessary, the circulars should contain the city ordinances and State laws, and should be distributed only to those directly interested.

A manual of the city health ordinances and State health laws should be drawn up, and new editions issued as occasion demands.

All information for the newspapers should come from the chief of this division. This may consist of material written for the newspapers, or it may be merely a statement to reporters of department activities. Department activities are almost always of good news value, and are printed readily. Friendliness should be maintained between the department and various newspapers.

This division should draw up the required ordinances of the department. It is preferable to have all health ordinances drawn up by a single individual rather than by the various heads of the divisions. The division chiefs would naturally assist in drawing up ordinances in which they were particularly interested. Before any ordinance is drawn up, it should be authorized by the Health Commissioner.

Publication of a special pamphlet for the use of school children, designed to teach them the fundamentals of hygiene and what each one of them can do to assist in health work, is suggested. It should be illustrated and compiled in conjunction with the medical division of the school board, and should be approved by the school board.

This division should also compile a brief history of the health department. This history should be kept up to date, but need not necessarily be published. It should be available to anyone who may desire health department information. A variety of further publications may, of course, suggest themselves.

LECTURES AND MOVING PICTURE SHOWS

Lectures given by capable and interesting speakers on various topics of sanitary import have distinct educational value. It is necessary that they be well advertised so that good audiences may be assured. The chief of this division should arrange for public lectures and assist private organizations in securing them.

Moving picture shows with films such as those that have been prepared in connection with the tuberculosis, milk and fly problems are very popular, and bring home sanitary truths to a class of people difficult to reach in any other way. The free exhibition of such films should be encouraged.

DISTRICT SURVEYS

As a special form of educational work, it is suggested that special district surveys be made from time to time. The general scheme would be to divide the city into a number of survey districts, and to concentrate in one such district as large a number as possible of the inspection staff of the Health Department. Then all of the health problems of the distric could be presented at one tme and considered in their relation to each other. A mass meeting of the residents of the distric would be arranged, at which short speeches from various members of the department would be given, presenting the sanitary status of the district and pointing out what the people could do to assist the Health Department. Stereopticon views showing conditions existing within the district, would be a valuable adjunct to such a scheme. These surveys should be made in each district as frequently as time permits.

MILWAUKEE
UREAU OF ECONOMY AND EFFICIENCY

Created by Common Council
For the Investigation of Departmental Accounts and Methods.
Resolution Adopted June 14, 1910.

BULLETIN NO. 18

HEALTH DEPARTMENT
3. COMMUNICABLE DISEASES

BY
SELSKAR M. GUNN

PREPARED UNDER THE DIRECTION OF
JOHN R. COMMONS

MILWAUKEE, WIS.
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LETTER OF TRANSMISSAL

CITY OF MILWAUKEE,

BUREAU OF ECONOMY AND EFFICIENCY.

Milwaukee, February 1, 1912

Dr. F. C. Kraft,
Commissioner of Health, Milwaukee.

Dear Sir:

We herewith append the report of the Bureau of Economy and Efficiency on the Control of Communicable Disease by the Health Department.

In Section I, the modern conceptions of disease-transmission and the ways by which progressive health departments are attempting to curtail preventable sickness and deaths resulting from such diseases are pointed out.

Section II consists of a discussion and analysis of the existing methods, and suggestions are made for improvements in this line of work.

Much of the material in Section II has a direct bearing on the whole question of the reorganization of the Health Department. As this subject is treated fully in a report of its own, only the necessary incidental consideration has been given it.

In 1910, nine hundred and sixty-five citizens of Milwaukee died from scarlet fever, diphtheria, typhoid fever, truberculosis, measles and whooping cough—preventable, communicable diseases.

It is our earnest hope that in this report we have succeeded in indicating that the effective measures to be used in saving these lives are (1) the making of control of quarantine by the health authorities complete, (2) the education of the public and the attainment of their co-operation, (3) the collection and recording of suitable histories of all cases of communicable disease, and (4) the scientific study and interpretation of these records by a competent epidemiologist.

Respectfully submitted,

(Signed) J. R. COMMONS, Director.
(Signed) B. M. RASTALL, Director.
(Signed) L. S. EVERTS, Director.

DIVISION OF COMMUNICABLE DISEASES

SECTION I.

GENERAL CONSIDERATIONS

Introductory The most important work of a health department is the control and prevention of communicable disease. Despite the efforts of health authorities there still occur in most communities many cases of these diseases and the number of deaths from them is very considerable.

In 1909 and 1910 the following cases of communicable diseases were reported to the Health Department of the City of Milwaukee. The deaths and in some instances the case mortality are shown.*

1909.

	Cases.	Deaths.	Case Mortality Percentage.
Diphtheria	835	120	14.3
Scarlet fever	1,801	191	10.5
Typhoid fever	437	78	17.8
Measles	1,938	27	
Smallpox	206	0	
Whooping cough	202	16	
Tuberculosis	730	396	
Totals	6,149	828	

1910.

	Cases.	Deaths.	Case Mortality Percentage.
Diphtheria	1,147	135	11.7
Scarlet fever	1,852	76	4.1
Typhoid fever	1,605	171	10.6
Measles	2,042	25	
Smallpox	61	0	
Whooping cough	461	28	
Tuberculosis	893	530	
Totals	8,061	965	

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*Health Department reports, 1909 and 1910.

In 1909, 4,886 deaths were reported from all causes, of which 828, or 16.9%, represent the deaths from communicable diseases; in 1910, 5,199 deaths were reported and 965, or 18.6%, from communicable diseases. Under ideal conditions, the lives of these citizens of Milwaukee might have been saved. While we are doubtlessly still a long way from reaching conditions which will prevent completely this great loss of life, yet it is certain that much can be done to diminish this serious drain on the greatest asset of a community,—its people.

Immensity of Problem

The economic loss to the community incurred by unnecessary loss of life is tremendous. Valueing each life at $5,000, which is a low and conservative estimate, we find that the actual cash loss to the City of Milwaukee from these preventable deaths in 1909 and 1910 amounts to the immense figure of $8,965,000. The loss due to sickness itself should also be considered irrespective of the outcome of the disease.

Disease and Dirt

For a long time it was believed that infectious diseases were produced largely by dirt. Dirt is now recognized often as an accompaniment of disease, and where present, it is likely that other conditions, which are actually capable of producing disease, are also to be found. As a result of such false ideas, the so-called pythogenic or dirt theory of disease became well established. With increased knowledge of the actual causes of certain diseases—that is, with the germs or microbes which produce them and particularly with the conditions of life of these germs both inside and outside of the bodies of man and other animals–it has been found that inanimate things are comparatively unimportant as vehicles of disease germs and that the most important bearer and disseminator of these germs is man himself. At times, of course, milk, water and foods become infected and give rise to epidemics; but in general it is safe to say that the greatest source of communicable disease is contact with other human beings, who harbor disease-producing organisms. It was thought that by proper quarantine methods extended over a period of years, many of the communicable diseases could be practically eliminated. The method was successful in the case of typhus fever and leprosy, cases of these diseases being very rare in countries where special efforts have been made to hospitalize and segregate sufferers. It has not been as successful, however, with scarlet fever and diphtheria. It is true that there has been a decided decrease in the prevalence of those diseases, but health officers have failed to secure the very great decrease which they anticipated. Severe epidemics, while not as common as formerly, are still not infrequent. For example, in Milwaukee in 1909 there were 1801 cases of scarlet fever and 191 deaths from this disease, and in 1910, 1852 cases and 76 deaths. A city cannot be really enthusiastic over its health conditions when it is possible for such an outbreak to occur.

Germ "Carriers" The problem of control of communicable disease has been further complicated in the past few years by the discovery that people may serve as carriers of disease germs long after they have completely recovered from an attack, and even when they have never suffered from any symptoms at all. The germs are lodged in different parts of the body, and are discharged from the intestines and bladder, in the case of typhoid fever; from the mouth and nose, in the cases of diphtheria, meningitis and other diseases. Persons in this condition are infinitely more dangerous to the community than if they were sick in bed at home, or in a hospital.

Besides these carrier cases, it is well known that many mild or atypical cases are never recognized. These are the so-called ''missed'' cases. Health departments are only commencing to take steps to control carriers and missed cases. The difficulties involved are, as can readily be seen, great, and at the present time it appears that the education of the people in the laws of personal hygiene would be the only fruitful method of attack upon communicable disease from these sources.

To put it bluntly, but truthfully, every person suffering from typhoid fever must have swallowed some of the bowel or bladder discharges of another individual who has had typhoid fever or who is acting as a carrier of the bacillus typhosus. The route of the dejecta of one person to the mouth of another is often a very short one. In case of sewage-polluted water, the route may be fairly long; but in the cases of infection of food stuffs by cooks or waiters, whose hands are soiled by their own body discharges, the route is decidedly short. The shorter the route, the greater the liability of contracting the disease, as the germs of most diseases die rapidly when outside of the body; and if the time of transit from one person to another be prolonged, the probability of contracting the disease is lessened.

Polluted water is rendered fairly safe by long storage. The germs of water-borne diseases, such as typhoid fever and cholera, die under the adverse conditions of an unfavorable environment. They are warm and rich food loving parasites, and do not long survive the hardships of living outside the bodies of men and animals. A modern health department must recognize all of these phases of the spread of communicable disease, if it is to do effective work.

Necessity for Epidemiologist

A health deparement should have at the head of the division of communicable disease an epidemiologist, a physician or sanitarian who is especially equipped with knowledge and experience to handle these diseases, a man who will study from all points of view every new case reported, to discover if possible the source of the infection. Too frequently it is found that a health department begins to take a live interest only when a considerable number of cases of a disease come to notice. Many epidemics have been written up after they were all over. More accounts are needed of the methods employed in *preventing* epidemics, and the manner in which outbreaks were effectively stamped out or checked before reaching epidemic proportions. The health commissioner, who obtains pure water for his city before an epidemic of typhoid fever devastates it, deserves more credit than the health commissioner who is praised after subduing one. The former is the less spectacular method, but it represents truer public health work.

Importance of Isolation of Patient

If agreed that the most common method for the spread of communicable disease is from man to man, either by direct contact, or through contact with things that have been freshly infected with the germs of disease (such as common drinking cups), it follows as a natural corollary that complete isolation of those afflicted with communicable disease is one of the most important steps towards preventing the spread of disease.

Modern health departments are insisting either on hospitalization, or on complete isolation in the home, of cases of the acute infectious diseases. Even in chronic diseases, such as pulmonary tuberculosis, it is being more and more insisted that the advanced cases be segregated in proper hospitals. Sanatoria treatment for the incipient or curable cases has not been as thorough in this country as in Germany and other European countries. The experience of England is instructive. England has been the leading country in isolating advanced cases of tuberculosis, and her tuberculosis death rate has decreased faster than that of any other country.

Weakness of Quarantine

Mere quarantining of the premises in which infectious disease is present, while it protects the general public if carried on in a thorough manner, is not sufficient to prevent secondary cases arising within the household. Strict isolation of the patient should be insisted upon, and if this be impossible the patient should be removed to a hospital.

The maintenance of quarantine and isolation is at best difficult. It can be obtained in many instances only by the most constant inspection. The sanitary inspectors detailed to this work should make repeated visits at unexpected times, and should have the power to summarily remove cases where the law is being disobeyed. Every individual suffering from a quarantinable disease, or the responsible person in cases where minors are the patients, who through negligence or wilfulness breaks quarantine, should be treated as a criminal offender and punished by a heavy fine and a jail sentence. People must be made to realize that violation of quarantine is among the most serious offenses against society. By their disregard for quarantine, offenders jeopardize the health and the life of others. Pleading ignorance should be no excuse. It should be the duty of the health department to forestall such excuses by notifying each household, at the time of serving the quarantine notice, of all the details to be followed in order to conform with the law.

Period of Quarantine and Isolation

It is evident that in order to control communicable disease properly, those afflicted must, if possible, be proven free from the disease germs before allowed at large. In those diseases where the germ is not known, it is essential that individuals be kept isolated until, as far as can be determined, they no longer harbor the organism. In cases of diphtheria, the method for raising quarantine is in many places based on the bacteriological examination of the nose and throat. Two consecutive negative cultures are required in such places, prior to the release of the case. In a large number of cities, the cultures must be taken by a physician of the health department, experience having shown that some physicians, anxious to release their patients early, fake the cultures by taking them from some other source than the throat of the patient.

It is well recognized that the germs of diphtheria may oftentimes be found in the nasal cavities even when absent from the throat. It is essential that the cultures for release be taken from the nose as well as throat. Where this is not done, it is probable that many persons still harboring the germs of the disease in their noses are permitted to go out and infect others.

Minimum Period of Quarantine—Diphtheria

It must also be recognized that the culture method is not infallible, cultures sometimes being negative when the patient still has the germs in his system. Accordingly, the best practice requires that all cases of diphtheria be quarantined for at least fourteen days before any cultures are permitted to be taken for release.

Minimum Period of Quarantine—Scarlet Fever

In the case of scarlet fever the period of quarantine is longer than that of diphtheria. It cannot be raised by bacteriological methods, as the organism which causes this disease has not yet been discovered. Quarantine varies in different places from two to six weeks. Sometimes the law stipulates that it be maintained until desquamation, or peeling, is complete. Experience has shown that some physicians will report cases as ready for release before peeling has completed, or while there is still a discharge from the ears, and as a result, many cities refuse to raise quarantine until the case has been passed on by one of the health department physicians. The longer periods, five or six weeks, are becoming more common in American cities, and have long been used in European countries.

Typhoid Fever

While typhoid fever is not a quarantinable disease, it is recognized as being very largely disseminated by contact. Nurses taking care of typhoid fever patients not infrequently contract the disease. The ability to still carry the germs of typhoid fever for a long time after complete convalescence is now well recognized. Some authorities estimate that from three to four per thousand of the population harbor the germ of this dread disease. With this in mind, some foreign cities, particularly in certain sections of Germany, require that both the bowel and bladder discharges of typhoid fever patients be examined bacteriologically and proven free from the germs of this disease before the patient is allowed freedom.

Smallpox Small pox, on account of its particularly objectionable character, is better quarantined than most of the other communicable diseases. Nearly all cases are taken to the hospitals and held there until all danger of communicating the disease is past. Minnesota and South Carolina no longer quarantine this disease; they merely placard it with a warning notice. This disease has been one of the most expensive to handle, yet we have a cheap and safe prophylactic of proven efficiency and value in vaccination. Those who desire to protect themselves can do so at a very slight cost, or at no cost at all in many places where free vaccination is offered by the health department.

Since this disease is one of the easiest to combat it seems unfair to tax the vaccinated or protected members of a community for the maintenance of small pox hospitals, special guards, and all the other expensive items that go with small pox cases and outbreaks, in order to protect those who through ignorance, mistaken beliefs, or negligence fail to protect themselves. It is unfortunate that in the case of this disease, which could be practically eliminated by the simple method of vaccination, prejudice and mistaken beliefs alone stand in the way.

Minor Diseases The so-called minor diseases, mostly of childhood — measles, German measles, mumps, chicken pox, and whooping cough—receive scant attention on the part of most boards of health throughout the country. It has been clearly shown, however, that some of these diseases are really important and should be controlled more effectively than they now are. It is also well known that many of the deaths of infants and children from pneumonia, broncho-pneumonia, and other diseases of the respiratory system, really should be charged against measles and whooping cough, as they are brought on by these two diseases.

Pneumonia

Similarly, pneumonia is largely a preventable disease and is undoubtedly passed on from one person to another. The health departments of certain cities, notably Chicago, have made special efforts to control it.

Disinfection

The disinfection of premises after recovery or death in cases of communicable diseases is practiced extensively as an aid to the control of such diseases. The importance of disinfecting presumably infected premises has been questioned of late by various eminent sanitary authorities, both in this country and abroad. Dr. C. V. Chapin, Superintendent of Health of the City of Providence and one of America's leading sanitarians, has had the courage of his convictions and has ceased disinfecting after scarlet fever and diphtheria unless specially asked for; in diphtheria cases he requires that all persons in the household *must* be proven free of diphtheria bacilli by culture before the disinfection is performed. This has been done for five years and disinfections are now quite rare in that city. There has been no evident bad effect. Secondary cases are no more frequent than before, and the diseases in question have not been more prevalent. Many officials, however, insist on the value and importance of terminal disinfection and consider it vital in the control of communicable diseases. For the present it seems safer to continue disinfection. If the future shows conclusively that disinfection is valueless it can readily be discontinued. It is expensive and the money could be used to advantage along other lines.

Education

The last branch of work of a health department in controlling communicable diseases consists in the education of the public to a standard of living that will make it easier for them to avoid contracting these diseases, and which will also induce them to do everything in their power to prevent the infection of others.

This short account of the methods of dissemination of comunicable diseases is given for the purpose of emphasizing the rave difficulties that have to be overcome by health departents if they are to be successful in their fight against the organms which deal such destruction to the people.

Granting then that physicians report all cases of communicale disease, the Health Department should control them by the ollowing agencies:

1. Through an expert epidemiologist, who shall study every case thoroughly to discover, if possible, the source of the disease, and who shall conduct the entire administration of the division.
2. Through quarantine and isolation of the patient—(hospital, if necessary).
3. Through constant inspection of quarantined premises and rigid enforcement of quarantine.
4. Through a bacteriologist, who shall assist in making diagnoses and in determining period of quarantine or isolation in certain diseases.
5. Through inspection by health department physicians before releasing from quarantine.
6. Through disinfection.
7. Through education of the people as to the prevention of disease, and the protection of others.

SECTION II.

PRESENT METHODS USED BY HEALTH DEPARTMENT TO COMBAT PREVENTABLE DISEASE AND RECOMMENDATIONS FOR THE IMPROVEMENT OF THE SERVICE

Organization At the present time the work of investigating and caring for cases of contagious disease is not centralized under one head, but is found scattered through various divisions of the Health Department. For example, the diagnostic bacterialogical laboratory, the contagious disease hospitals, the medical assistants to the Commissioner, and the quarantine and inspection work are all under separate divisions. The organization existing at the present time is shown in Chart I.

The proposed reorganization of all those divisions charged with the control and care of communicable disease is shown in Chart II.

A discussion of this proposed reorganization will be found in the report on "Reorganization of the Health Department."

DETAILED REPORT ON ACTIVITIES OF EXISTING DIVISIONS DEALING WITH COMMUNICABLE DISEASES

Method of Reporting Cases Notice of a case of communicable disease may come to the department in a number of ways. Usually the physician in attendance telephones immediately upon positive diagnosis of a case. The telephone report is later confirmed by a postal card notice, which is used to report all diseases on the reportable list. The list includes typhoid fever, scarlet fever, small pox, chicken pox, diphtheria, measles, German measles, whooping cough, cerebro-spinal meningitis, erysipelas, and tuberculosis of any part of the body. This card is also used to report the termination of cases on recovery or death. If the disease does not require quarantine, the physician will frequently not report at once, and in the milder diseases, such as chicken pox, measles, and whooping cough, it is certain that many cases are never reported. Neighbors sometimes become suspicious that disease is being concealed and telephone to the department. In this case an inspector is sent to the house. If he finds any suspicious symptoms one of the medical assistants to the Commissioner is sent to diagnose the case. The medical assistants then report all such cases in the same way as the ordinary physician. Occasionally the school authorities, through their medical inspectors, nurses, truancy officers or teachers, report cases for diagnosis. These are handled in the same manner as suspected cases, and are turned over to the medical assistants for diagnosis.

Another important source of information concerning communicable disease is the department bacteriologist. All positive cases that come to the bacteriologist's attention are reported to the contagious disease division. The cases are treated by the Health Department as if the physician had reported them directly.

The law requires that physicians and others make a written report. It is difficult to enforce this law. Telephone notification of the case by the physician is usually sufficient, although it is preferable to have his written record of the case on file in the office.

Methods of Quarantining

the case is given a number, a different ser- division in any of the ways mentioned above, When notice reaches the contagious disease ies being used for each disease. If the case is one requiring quarantine, notice is given the placarder to card the house. The placarder is supplied with two quarantine notices, one is served personally on some responsible occupant of the quarantined premises, and the other is returned to the office with the placarder's certification of service. The placarder also obtains a record of the facts in the case on a separate form. Both the duplicate quarantine notice and the record of the case are filed in an envelope in which are placed all papers relating to the case, including the original report. These envelopes are filed by the number of the case, and are kept for one year. The duplicate notice of quarantine, with the report of the placarder, is sent to the Truancy Division of the School Department. These papers are returned for filing within a day. Index cards of cases reported are made out, different colors indicating different diseases. These cards are filed as follows: houses under quarantine, by streets; tuberculosis and typhoid cases, by name; and miscellaneous cases by number. The library is notified of all cases, and the schools of cases occurring in the families of any of the pupils.

The placarder notifies the householders of the precautions to be observed, and leaves with them a copy of the special folder on quarantine issued by the department, together with all information necessary to make the quarantine effective. Where necessary, he seals some of the doors, so that bread winners can live in parts of the house without exposing themselves. Two placards are put up, one at the front, the other at the rear entrance. When a house is occupied by more than one family and the families have a common entrance or entrances, no placard is put on the outside of the house, only the private entrance of the family, in which the disease is found, is placarded.

At times, when the placarder is unable to attend to all of his work, or when a number of cases are reported at one time, the sanitary inspector, in whose district the case occurs, is assigned the case. This makes it necessary for all the sanitary inspectors to be familiar with all the work of quarantining. The same is true with regard to disinfection.

When the case is to be sent to the Isolation Hospital the assistant chief fills out a special form and sends it to the matron of the hospital.

Inspection of Quarantined Premises

previous day. He is required to make an in-
ease that were reported in his district on the
is notified of all cases of quarantinable dis-
Every morning the inspector of each district
spection to see that proper quarantine is maintained. He visits each place daily, until quarantine is raised, acting as a messenger between the isolated home and the outside world in supplying the wants of the quarantined family. If these services of the Health Department are not desired, the family so signifies in writing on a card supplied by the inspector. If the daily visits are desired, this card is left at the house, and each call of the inspector recorded on it. This card record is

ultimately returned to the office by the disinfector, who collects it at the time of disinfection. A monthly report of the visits to houses under quarantine for contagious diseases is made by each inspector.

Disinfection When the doctor notifies the Health Department that a case of scarlet fever is terminated, or when the bacteriologist notifies the department in a case of diphtheria that two consecutive cultures have been found negative, the disinfectors are given written instructions by the assistant chief to fumigate the premises and raise the quarantine. This disinfection notice is then returned by the disinfector, indicating that the work has been done. At the same time he leaves at the house a certificate, which on presentation permits the quarantined inmates to resume attendance at school and use of the Public Library. The disinfection slips are destroyed, but the disinfectors keep note books in which they record the name, address, number of cases, number of rooms disinfected, amount of fumigating material used and the date. At the time of disinfection, the disinfector collects the inspector's card, which the latter has used in connection with the inspection of the quarantined premises, and returns it to the office.

RECOMMENDATIONS FOR IMPROVING METHODS OF REPORTING

1. The postal card used is not particularly well arranged for reporting cases, recoveries, and deaths. Form 1 is recommended. Besides differing slightly from that now used, it emphasizes the fact that tuberculosis should *not* be reported on this form. It will be noted that at the present time tuberculosis is reported on the same kind of card as scarlet fever and diphtheria. This is not advisable, as certain additional information of a special character should be submitted for this disease. (As the character of the report in cases of tuberculosis is so different from that in the other communicable diseases, it is considered separately under tuberculosis).

2. As so many cases are reported by telephone, it is advisable that some form be used to take down the name, ad-

dress, and other pertinent information with regard to the case. Form 1[*] can be used for this purpose. The time of receipt of message should also be noted in the corner of the card.

3. It is recommended that the Health Department make an arrangement with the Post Office authorities whereby all reports of doctors and others may be posted without stamps, the department to pay upon receipt. This is done in a number of places, and has the great advantage of preventing the waste of considerable money for stamps and post cards which are never returned to the department.

4. It is recommended that the Health Department distribute to all physicians suitable boxes or cases in which to keep reporting cards of all kinds, birth and accident certificates, and other forms issued by the Health Department to physicians. Such cases are in use at the present time in Richmond, New York, and other cities. Besides enabling the doctor to keep all forms together so that he can find a form when the occasion arises, it has the additional advantage of continually reminding him of his obligations to notify the Health Department of all cases of reportable diseases and to register births and accidents. The boxes used in Richmond cost twelve cents a piece. Inside the cover there is a printed condensed schedule of the duties of physicians required by ordinances.

RECOMMENDATIONS FOR IMPROVING METHODS OF QUARANTINING AND HISTORY TAKING IN QUARANTINABLE DISEASES

Case History

It is recommended that the method of serving the quarantine notice now used and previously described be continued.

A study of the blank form used in taking the history of quarantinable diseases and filled in by the placarder, shows it to be very incomplete. The reason for taking *any* history is to get all evidence that might throw light on the source of infection of the case in question and of other cases. It should be thorough and scientific, and to this end Form 2 is recommended for scarlet fever, diphtheria and smallpox. Of course, unless each history is subjected to careful, scientific and analytic study by some competent person, it would be a waste of time to find out all the particulars of a case. As emphasized in the introduction, the efficiency of this division depends in a large measure on its supervision by a competent epidemiologist.

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[*] The forms referred to in this report may be seen in the files of the bureau.

In looking over fifty envelopes containing the data of fifty cases of diphtheria reported in 1911, it was found that ten had no history of the case at all; in fifty cases of scarlet fever, twelve were deficient in this respect. This is partly due to the fact that whenever a case is taken to the hospital for treatment no history is taken. It is immaterial, of course, where the case is treated as far as the epidemiology of the disease is concerned. What is wanted is a proper history of every case so that the proper deductions may be drawn as to where the disease was contracted. In one of the fifty envelopes of the diphtheria cases, there was found only a postal card reporting the case, a slip from the laboratory stating that the case was positive, and another slip of later date stating that the case was now ready for release on negative cultures. It was stated in the Health Department that as there had been already a case of scarlet fever in the house, of which the history was known, it was not considered necessary to take the history of the case of diphtheria.

It is essential that the history of all cases, whether they be removed to the hospital or not, whether they be secondary cases occurring in the house, or cases of another quarantinable disease, shall be obtained.

It is evident from what has been stated earlier in this report, that quarantine and isolation should be maintained in as perfect a manner as possible if disease is to be controlled. This necessitates a thorough knowledge on the part of the placarders as to what real quarantine and isolation mean. A circular of information is now distributed to all quarantined families, but personal direction as to what steps are to be taken is more essential. Every case differs in some respect in its method of handling. Differences in the kind of employment of the members of the family, in the nature of the dwelling, and in the character and nationality of the people, make it extremely difficult to formulate rules that would be applicable in all instances where infectious disease exists. The placarders do not visit the premises again after putting up the placard and quarantining the family. Further visits are made by the district sanitary inspectors. It is manifestly impossible for the placarder to give verbal notice in the office to each inspector with regard to what measures he has ordered. It is therefore recommended that the placarder fill out a special card for the use and benefit of the district inspector, stating the main facts of the case, and what was ordered to be done (Form 3). This is practiced in Chicago with good results.

RECOMMENDATIONS FOR IMPROVING METHODS OF TERMINATING QUARANTINE

Period of Quarantine A study of 200 cases of scarlet fever and 200 of diphtheria occurring in 1911 was made in order to determine the period of quarantine. The results are given in the following tables.

TABLE. I.

SCARLET FEVER.

HOME.		HOSPITAL.	
No. of Cases.	Days Quarantined.	No. of Cases.	Days Quarantined.
1	38	1	54
1	35	1	43
1	33	1	39
1	32	2	38
2	31	2	36
3	30	5	33
1	29	3	32
4	28	1	31
1	27	1	30
9	26	1	28
6	25	2	25
8	24	1	23
13	23	2	22
15	22	1	19
30	21	1	14
11	20	1	13
12	19		
7	18		
8	17		
10	16		
25	15		
5	14		
174		26	

Average period of quarantine for 174 cases treated at home, 20.7 days.

Average period of quarantine for 26 cases treated at hospital, 30.7 days.

TABLE II.

DIPHTHERIA.

HOME.		HOSPITAL.	
No. of Cases.	Days Quarantined.	No. of Cases.	Days Quarantined.
1	43	2	19
1	37	1	18
1	36	1	17
1	34	1	16
1	33	2	15
1	32	2	14
3	31	4	13
1	30	4	12
3	29	4	11
2	28	2	10
4	27	2	8
2	26	1	7
6	25		
3	24		
3	23		
8	22		
8	21		
12	20		
11	19		
15	18		
11	17		
15	16		
30	15		
27	14		
1	13		
2	12		
1	8		
174		26	

Average period of quarantine for 174 cases treated at home, 18.9 days.

Average period of quarantine for 26 cases treated at hospital, 12.8 days.

Two hundred consecutive cases in which there was recovery were taken in each instance.

Scarlet Fever fever that the average period of quarantine It will be noted in connection with scarlet in the cases treated at home was 20.7 days; and of those treated in the hospitals 30.7 days. In making these determinations, both the day of report and the day of fumigation were included, so that the period in many instances was probably one day shorter than the figures in the table would indicate.

The rule of the State Board of Health, which regulates quarantine throughout the state, requires that cases of scarlet fever shall be quarantined for a period of at least three weeks and as much longer as the severity of the case may demand,

and the quarantine of all persons living in the family with, or in any way exposed to, the patient while the house remains quarantined, unless said persons submit to thorough disinfection of their clothing and take up their residence in some other house during the time that said quarantine is maintained.

In the official folder (No. 1) issued by the local Health Department the following are given as the terms of quarantine for scarlet fever:—

"The minimum quarantine is twenty-one days.

"Release from quarantine is permitted after the twenty-first and prior to the thirtieth day only upon a certificate signed by the attending physician (and a medical assistant of the Health Department, but only if so requested by the attending physician) stating that desquamation is complete, and that there is no danger of contagion from the patient."

An inspection of Table I shows that of the 174 cases treated at home, seventy-eight or 44.8% were released under three weeks.

Release from Quarantine— Scarlet Fever

Quarantine in cases of scarlet fever is removed, at the present time, on the receipt of notification from the doctor. There is no inspection made of the patient to determine whether or not he has fully recovered. The department feels that if it is willing to take the doctor's diagnosis of a case, it should also take his statement with regard to recovery.

This appears to be a very dangerous procedure. It is certain that many cases released must still be actively desquamating. It is a disputed point as to whether the desquamated skin in itself carries the organism of scarlet fever; but experience has shown that it is reasonably safe to assume that by the time a case of scarlet fever is through peeling, the patient will also have eliminated the specific organism and will no longer be capable of spreading the disease. While many doctors are careful, and do not report cases ready for release prematurely, it is well recognized that many are not careful. It is therefore strongly recommended that before all cases of this disease be released from quarantine they shall be inspected by one of the medical inspectors of the department who shall make a thorough examination to see that the patient is free from desquamation, and otherwise free from the disease.

At the present time the attending physician can request a medical assistant of the Health Department to examine the convalescent and certify that there is no danger of contagion from the patient. This occurs only in a few cases.

A study of the charts in the addenda shows that scarlet fever was very prevalent in 1909 and 1910, there being 1801 and 1852 cases in these respective years. In the first six months of 1911, according to the records of the department, 912 cases were reported. It is not unreasonable to believe that there may be at least a partial correlation between the short period of quarantine and the prevalence of the disease.

The school authorities refuse to permit children to return to school for six weeks dated from day of the discovery of the disease, but the opportunity for infection outside of the school building is not inconsiderable.

It is interesting to note that the twenty-six cases treated in the hospital were held on the average ten days longer than those which were kept at home. This would seem to indicate that the physician in charge of the hospital is more careful than many of the physicians who look after private cases.

Period of Quarantine—Diphtheria

In the case of diphtheria it was found that the average period of quarantine in the home was 18.9 days and in the hospital 12.8 days. Owing to the fact that two negative cultures from the throat of the patient are required to release the quarantine, there is an added check on the physician, and the danger of a premature release from quarantine is not as great as in cases of scarlet fever.

The State Board of Health issues the following ruling with regard to quarantine of diphtheria:

"For the patient: Quarantine for fourteen (14) days after the beginning of the disease.

"For persons associated with or in the family of the patient: Quarantine until after death or until recovery of the patient and disinfection of person, clothing and premises. Every person convalescent from diphtheria must remain isolated until two successive cultures from the throat made three days apart show the absence of diphtheria bacilli."

It is interesting to note that the period of quarantine in the hospital is on the average six days less than in the private home. This may be accounted for by the fact that in the hospital all cases are properly nursed under medical supervision, while in the homes the vast majority of cases do not have such expert service and as a result the patient's throat is not freed from the organisms of the disease as rapidly as might be.

Release from Quarantine—Diphtheria

In cases of diphtheria, it is recommended that a medical inspector of the department take the cultures for the release, and that besides taking a culture from the throat, the nose be also cultured whenever possible. At the present time only one swab is used and a culture from the throat alone is required. The nasal cavities are very apt to lodge the diphtheria bacillus and a false sense of security is engendered when a patient is released merely on two negative cultures from the throat. All persons who have been in contact with the patient should also have a culture taken as they are likely to be acting as carriers of the diphtheria bacillus.

Recapitulation

To recapitulate, it is recommended that where a patient is convalescent from scarlet fever and diphtheria, and no longer in need of medical service, the attending physician shall send in a notice to that effect to the department, and the department shall then assume entire charge of the case with reference to releasing from quarantine, taking the necessary cultures in diphtheria, and examining the patient in cases of scarlet fever as mentioned above.

This is the customary procedure in most large cities of this country, and it has proven practical and valuable. Most physicians are glad to be relieved of the responsibility of releasing their patients from quarantine, and to not have to stand the criticism of a family when negative cultures are not forthcoming, or when a child continues to desquamate for a long time. It has also been pointed out by several prominent health commissioners that another advantage to the physicians lies in the fact that if the Health Department assumes absolute responsibility in releasing the quarantined family, there is little or no chance for the careful practitioner to lose his practice to the unscrupulous doctor, who endeavors to earn a reputation by releasing patients from quarantine in quick time.

Business Procedure—Medical Assistants

In connection with this work on the part of the district medical inspectors of the Health Department, certain forms are necessary. When a physician reports a case as terminated as far as he is concerned, the clerk of the Communicable Disease Division shall communicate this fact to the proper district medical inspector. The clerk shall telephone to the medical inspector at a certain appointed time every morning and notify him of the cases awaiting to be released, and also of the results of the release cultures sent in by him on the previous day. The inspector shall fill out a copy of Form 4, whenever a case is ready for release, and shall mail it to the department. When this is received, the disinfector shall be notified by means of a disinfection notice to proceed with the disinfection and raise the quarantine. At the present time, the district medical inspector sends to the Chief of the Division of Communicable Disease a daily postal report of the work performed. It is recommended that Form 5 be used for the daily reports of medical assistants. The clerk shall make out from these reports a monthly report, Form 6, of the work done by the medical assistants.

RECOMMENDATIONS FOR IMPROVING METHODS OF DISINFECTION

The notice used in notifying the disinfectors of premises to be disinfected is approved. It is recommended that Form 7 be used by the disinfectors and placarders in making their monthly report of work done.

It is also recommended that all inspectors be thoroughly trained in the manner of disinfecting premises.

The present disinfection certificate, permitting quarantined persons to return to school and to resume use of the public library, is approved.

RECOMMENDATIONS FOR IMPROVING METHODS OF INSPECTION OF QUARANTINED PREMISES

At the present time there is no way of determining what orders were given by the quarantine officer to the infected family and therefore the inspector cannot tell if the family is disregarding such orders. As previously recommended, the quarantine officer will fill out Form 3 for each case visited, and this will be handed to the inspector in whose district the case is reported in place of inspectors' memorandum now used. This will enable the inspector, before visiting the premises, to be conversant with each case and to know what orders have been given by the quarantine officer. The inspector shall fill in the result of his first inspection on the back of Form 3, and return it to the office.

In place of the blank, now used for recording the daily visits of the inspector, Form 10 is recommended. This is to be left at the premises by the district inspector on his first visit, being filled in by him at each further visit, and ultimately, when the case is concluded, it shall be returned to the office by the disinfector, where it shall be filed with the other reports belonging to the case. Where violations of quarantine are found it is recommended that Form 8 be used by the inspectors to record the details of the violation. Violations of quarantine shall be immediately reported to the office.

It is recommended that the district inspectors make a daily report on Form 9 of the amount of work done by them for the Division of Communicable Disease. This form, which provides spaces for each day of the month, shall be kept at the office, and the monthly totals made from it.

It is recommended that all cases of violation of quarantine be prosecuted, except under very unusual conditions, and the facts well advertised in the newspapers and department bulletins.

It is recommended that the present method of discontinuing the daily inspections of quarantined premises at the request of the family be abandoned, except in those cases where it is felt certain that the people will obey the quarantine regulations.

It is recommended that the placarder and disinfectors be called quarantine officers and their duties made the same for all, so that these three men shall both placard and disinfect.

Education of Inspectors

In order that the inspectors, placarders, and disinfectors may be thoroughly conversant with the work of this division, so that they can act intelligently and efficiently, it is recommended that the Division of Education and Publications arrange a proper course of instruction for them. This is discussed in the report dealing with the functions and activities of that division.

RECOMMENDATIONS FOR IMPROVING METHODS OF KEEPING RECORDS OF QUARANTINABLE DISEASE IN THE OFFICE

It is recommended that the present method of keeping the records of scarlet fever and diphtheria in envelopes be further developed. Instead of filing the envelopes by number, it is suggested that they be filed by name of patient and be made large enough to hold all the forms used in connection with each case.

It is recommended that the front part of the envelope be printed as shown on Form 11, for scarlet fever, and a modified form of No. 11, for diphtheria. These envelopes shall be filed by different diseases and different colors should be used for each disease.

At least once a week these records shall be looked over, so that no cases shall be neglected. Each envelope shall contain a complete record of all steps taken in regard to any particular case, including,—

Postcard or telephone message reporting case, recovery, death,

Duplicate quarantine notice,

Quarantine call,

History card,

Termination report from medical assistant,

Disinfection notice,

And any other notices and communications bearing on the case.

It is recommended that the card index now used to record cases of these diseases be continued, the cases being filed by address. As soon as a case is concluded, the envelope, after having been properly filled in, shall be transferred to a part of the file where finished cases are kept, and after a year has elapsed the records contained in the envelope may be destroyed. The front part of the envelope shall be saved, and filed as the permanent record of the case.

It is recommended that the clerk keep a register of all cases and that they be here recorded by case number. These forms shall be bound in books and different books used for different diseases. This record will give the case number, name and address of patient, date reported, date placarded, date terminated, and date disinfected. The amount of material used to disinfect shall also be noted. From this register the clerk will be able to make his monthly report of the number of cases of the various diseases reported. It will also enable him to keep track of each case and note its progress. With the envelopes filed by name, the cards by address, and the register kept by case number, it will be possible to look up any one at a moment's notice.

Spot Maps It is recommended that spot maps be kept for the various communicable diseases. As soon as a case is reported a spot should be placed on the map t the approximate location of the premises and a pin with colored head placed over the spot. As soon as the case is ver, the pin is to be removed, but the spot will remain as he permanent record of the case. A new map for each im-ortant disease should be made each year. These maps are f great assistance in keeping track of the location of cases nd point out immediately the occurrence of localized out-reaks.

Blackboard Record

It is further recommended that a blackboard record be kept of all cases of the important diseases. Form 12 is recommended for this urpose. It would show at a glance the number of cases on hand and the number discharged. It would also be arranged o that a comparison could be made with the preceding twelve months and marked increases or decreases readily noted.

TYPHOID FEVER

Cases of typhoid fever are reported on the regular reporting blanks and one of the inspectors is sent out to take a history of the case on a special form. An examination of some of these cards showed that the inspector was not always successful in getting all the information asked for. No track at all was kept until 1911 of secondary cases; now the corner of the original index card is clipped to indicate that there was a recurrence. The rear door of the residence housing typhoid fever victims is placarded for the benefit of the milkman. When the inspector returns the history blank, the case is recorded on a card which is filed by the name of the patient. A special note book is kept for typhoid fever by the chief of the divison of contagious diseases showing the case number, date of report, attack, recovery, death, duration of disease, date of removal from city, positive bacteriological examination, and origin of disease where known.

RECOMMENDATIONS FOR IMPROVING THE METHODS USED IN HANDLING CASES OF TYPHOID FEVER

The present form used for taking the history of the case is approved. It is recommended that the envelope system advocated for keeping record of scarlet fever and diphtheria be used in connection with typhoid fever, and that the envelopes be filed by name of the patient. It is further recommended that the card index be filed by address and not by name; and in addition that all cases of typhoid be recorded in the register.

In all cases where the patient is not being attended by a qualified nurse, reinspection should be made by the inspector in whose district the case occurs to see that the necessary precautions are complied with.

It is well recognized that secondary cases of typhoid fever are extremely common and also that many typhoid fever patients continue to harbor the organism of the disease in their systems for a considerable period of time after recovery. An effort should be made by the inspector to have the disinfection of the dejecta continued for at least a month after complete convalescence.

It is recommended that the Health Department distribute free disinfectants in cases where poverty prohibits their purchase. Five per cent carbolic acid for urine and chloride of lime for feces are recommended.

It is recommended that the Division of Education and Publications prepare a special folder, to be left at the house where the patient is confined, pointing out the means of preventing the infection of others.

MISCELLANEOUS DISEASES

Small Pox When a case of small pox is reported, a medical assistant is sent by the Health Department to diagnose the case, and to see that the case is immediately removed to the hospital. An index card, used for miscellaneous diseases, is filled out and filed by number. The premises are disinfected, and an effort is made by the physician or the medical inspector to vaccinate all persons who came in contact with the case. Free vaccination is offered. If the persons exposed refuse to be vaccinated, the children are barred from school for twenty-five days. No special history blanks are used in connection with small pox.

Minor Deseases

Minor diseases, such as measles and whooping cough, do not seem important when compared with the diseases before discussed. The following table, however, shows that they are not to be disregarded:

Year.	Deaths from Measles.	Deaths from Whooping Cough.
1900	36	46
1901	17	21
1902	36	49
1903	1	43
1904	16	6
1905	4	24
1906	34	30
1907	5	16
1908	18	35
1909	27	16
1910	25	28

Chickenpox is important only in so far as it may be mistaken for smallpox.

At present nothing is done in cases of these minor diseases besides keeping the card index, and reporting the cases to the schools.

Recommendations

It is recommended that the envelope method of record keeping be extended to smallpox and that blanks similar to Form 11 be used for it and miscellaneous diseases. Form 2 can also be used for recording the history of smallpox and cases of other diseases; besides this, the names and addresses of persons exposed and persons vaccinated should be kept on a separate sheet as is now done. It is further suggested that the Division of Education and Publications make a special effort to constantly remind the public of the importance and value of vaccination, increasing by suitable publicity the amount of free vaccination now done.

At present it does not seem advisable to prescribe a complete system for handling minor diseases, but with the increase in the corps of men under the Health Department, the forms and the envelope system recommended for diseases of a more serious type may be extended to the minor diseases.

It is recommended that the Division of Education and Publications prepare proper circulars of information pointing out the dangers of measles and whooping cough; and that these be distributed generally throughout the city, and also that a copy be mailed in every instance to the mother of children reported to be suffering from these diseases, so that she may be warned of the danger.

TUBERCULOSIS

Present Methods Used to Combat Tuberculosis

Present methods used by the Health Department in connection with the registration and recording of cases of tuberculosis are recognized as being very inadequate.

Cases of tuberculosis are reported on the same post cards that are used for the acute reportable diseases. When a case is reported to the Health Department it is registered on a card index, on which is recorded the name and address of the case and any other slight information that the physician may have noted on the post card. These cards are filed by name and nothing is done to follow up the case, so that the records at the present time are incorrect. When a death from tuberculosis is reported by the Registrar, or when a case of removal comes to the knowledge of the Health Department, a disinfector is sent to fumigate the premises and take the history of the case on a special blank form.

It does not seem necessary to point out the manifest defects of the present system and the following recommendations are made with regard to the registration and record keeping of this disease. These are based largely on the experience of New York and Chicago and some smaller cities.

RECOMMENDATIONS

It is apparent that the ordinary form used by physicians to report acute diseases is not applicable to tuberculosis and it is recommended that Form 13 be adopted by the Health Department as the form for use by physicians in reporting cases of this disease. This form has been used elsewhere with good results. It is simple for the physician to fill out, as the arrangement of the questions calls for short answers. The use of this form will supply all information necessary to determine whether or not further action on the part of the Health Department is required. This same form is also recommended for use by hospitals and dispensaries in reporting cases. It is recommended that this report be mailed in an envelope. It is suggested that the letter, appended to this report, be sent by the Health Department to all physicians, notifying them of the new method of reporting tuberculosis and asking for their cooperation.

When a report is received by the Health Department, it is recommended that the clerk in charge of the tuberculosis files record on an envelope, Form 14, the name and address of the patient and other information indicated by the report cards. These envelopes shall be filed by name of patient, and all reports, inspection and disinfection notices, and letters concerning each case shall be permanently kept in their own respective envelopes. It is recommended that all cases be registered in a tuberculosis register by number. The plan recommended for the registration of the other communicable diseases is applicable in this case.

It will be noticed that there is space on the front of the envelope for all records of removals and disinfections, and the final disposition of the case is likewise eventually recorded. In the case of removal, the disinfection notice on the envelope refers to the place vacated and not to the new location of the patient. These envelopes are to be kept in two files, one for those living, and another for cases which have died or permanently removed from the city.

The Registrar of Vital Statistics shall notify the clerk who has charge of the tuberculosis records as soon as a death certificate is received in which the cause of death is stated to have been tuberculosis, as is now done, and the clerk shall search the records to see whether or not the case has already been reported. If the case has been reported the usual disinfection shall be ordered. If the case has not been reported a new envelope shall be made out for it and the clerk shall write a letter to the physician who signed the death certificate asking for an explanation of his apparent neglect. The premises in which the patient died shall also be ordered disinfected and the disinfector shall endeavor to find out, at the time of disinfection, the history of the case, using a regular tuberculosis report card for this purpose. It follows that, if it be discovered that the patient has lately removed from another location in the city, this place shall also be ordered disinfected.

If the physician in making his report states that he is desirous of having a nurse visit the case, the clerk, on making out the new envelope for the case, shall in addition fill out an inspection blank (Form 15). This form shall then be handed to the visiting nurse, who shall return it after having visited the case. As subsequent visits of the nurses are recorded on this same card, it shall be kept in a separate file until the patient dies, recovers, removes from the city, or othewise passes out of the control of the Health Department, when it shall be filed in its proper envelope. It is realized that a nurse makes a much better visitor in cases of tuberculosis than a uniformed inspector. If, however, the inspection has to be made by an inspector the same form shall be used. The clerk shall note the contents of inspection cards when they are returned to him and shall see that the necessary steps are taken where indicated. It is suggested that where special steps seem to be necessary along the lines of assistance, or where care of one kind or another seems advisable, that the case be referred by the clerk to the Secretary of the Tuberculosis Commission.

The bacteriologist of the laboratory notifies the clerk of all positive examinations of sputum and the clerk shall make a record of them and note whether or not the cases are reported by the doctor. He shall also make out an envelope for the case. If no word be received from the physician in the course of a week the clerk shall telephone to him and remind him to report the case.

It is recommended that the clerk shall make out in each instance a record of the case on a house register. This shall consists of a card 3″ x 5″ on which shall be re-recorded the date, address and name of patient (Form 16). If either death or removal occur at a later date the fact shall be recorded on the house register and a note as to the date of disinfection of the premises shall likewise be added. These cards shall be filed by address.

Deaths reported by the Registrar, which have not already been reported by physicians, shall also be recorded in the house register. This register will then be a record of the location of all cases of tuberculosis in the community that are known and also in the course of time will give the history of each building as far as tuberculosis is concerned. In order to increase the value of the house register it is recommended that as time permits the clerk make out cards for all houses in which there have occurred deaths from tuberculosis in the past twenty years. Such a house register grows in value as time goes by.

Any system of records for looking after tuberculosis will soon become inaccurate, incomplete and of no value, unless special pains are taken to follow up the cases in the city and find out whether or not they are still located at the addresses shown by the records. Also, experience has shown that unless some comprehensive method be used in connection with the verification of addresses, many premises, presumably infected, are not disinfected, cleansed and made safe.

The sanitary inspectors at the present time are greatly burdened with work and are unable to do certain kinds of inspection work which they should be doing. Their districts are large and it would be an added burden to have them look up all cases of tuberculosis within their districts. In order that the department's tuberculosis records may be kept in the proper manner, it is recommended that the Chief of Police be asked to cooperate in the movement to eliminate the great scourge of tuberculosis from the city by having the day patrolmen look up the cases in their districts. The list of cases shall be supplied to the Police Department by the Health Department once a month. There are eighty-nine day patrolmen and fourteen district sanitary inspectors; consequently the districts to be covered by the patrolmen would be much smaller than those of the sanitary inspectors. Each patrolman, therefore, would have few cases to look up. Another advantage lies in the fact that a patrolman is much more familiar with the people in his district than is the sanitary inspector.

It is recommended that the above mentioned lists be prepared on Form 17. The clerk shall fill in the date, address, and the name of the patient in each district, and the patrolmen shall note in the proper columns whether or not the patient is still located at the given address, or whether he or she has died or removed elsewhere. If the patient has removed, the new address shall be ascertained if possible.

The lists when returned to the clerk shall be gone over by him, the necessary orders for disinfection issued where removals have occurred, and the proper records of the new address of the patient made out on the appropriate envelope. These records shall be corrected once a month by the clerk, deaths checked off, new cases added, removals checked off and transferred to the proper list, if the patient still lives within the city limits. When the time comes for the next inspection these corrected lists shall be given to the patrolmen. The house register shall be corrected by the clerk from these lists.

New York Method for Following Up Cases

It is suggested that later on when the physicians have become accustomed to the new method of reporting and to the increased activity of the department, that the New York method of following up cases also be adopted. In that city every doctor is required to furnish every month, on special blanks supplied by the Board of Health, information as to whether or not the patient is still under his professional care or whether the patient has moved. By means of this method the department is able to learn of many removals, and complete disinfection of the vacated premises is made possible.

Opportunities for Co-operation

Health departments throughout the country have realized within the last few years the extreme importance of keeping careful track of all cases of tuberculosis. Besides the advantage of being able to disinfect, cleanse and render safe apartments which have been inhabited by a consumptive, there is also the great advantage of knowing where the tuberculosis members of the community are living, as they can then be directly reached and educated. The Division of Education and Publications of the Health Department and the Tuberculosis Commission are prepared to do all in their power to educate the consumptives in the city and those who live with them in the precautions necessary to prevent a further spread of the disease.

Form 18 is recommended for the special use of hospitals and sanitoria receiving cases of tuberculosis, to report date of dismissal and their destination, so that the records in the city may be kept correctly.

Monthly Report of Chief of Division

Form 19 is recommended for use by the chief of the division in making his monthly report to the Health Commissioner. It should be made in duplicate, the duplicates being retained by the chief for the purpose of making his annual report.

APPENDIX

Charts 3, 4 and 5 are interesting as showing the course run by Diphtheria, Scarlet Fever, and Typhoid Fever—three common and preventable diseases—in Milwaukee in the last eleven years. The figures are taken from the annual reports of the Health Department which are set up in Table 3. The curves represent death rates per 100,000 of population. The marked fluctuations in all three curves indicates that the control of communicable disease is still far from satisfactory. A typhoid fever death rate of 46 per 100,000, as in 1910, indicates a most serious condition.

Chart 6 affords a comparison of the incidence and fatality of these three diseases during the first and last halves of the decade 1901-1910. It is evident that Milwaukee has not only suffered unduly from epidemics of communicable disease, but that conditions have certainly not improved in the last five years. It is believed that the placing of the commnicable disease work in the hands of a competent epidemiologist would be followed by a marked improvement.

Table 4 shows the number of deaths from various communicable diseases in the last eleven years. The relative insignificance of smallpox—six deaths in eleven years—as compared with the so-called minor diseases—measles and whooping cough, 533 deaths in the same period—is food for thought. The loss of 533 children in eleven years, more than from scarlet fever in the same period, demands that these so-called minor diseases be most carefully studied and combatted.

The figures for pneumonia and tuberculosis have been calculated into death rates per 100,000 population in Table 5. The fall in tuberculosis (barring 1910) is consistent with the experience of other cities and countries, and would seem to indicate better standards of personal hygiene among the people.

Pneumonia is increasing here as elsewhere. It has been placed on the list of reportable diseases by some health departments. It is certain that the disease is frequently transmitted from person to person; and highly probable that many of the deaths from this cause could be prevented under better conditions of living. Campaigns against penumonia are being conducted by health authorities in various places.

Chart 7 affords a comparison of the fatality of these two diseases during the first and last half of the decade 1901-1910.

Tentative Form of Letter To Be Sent to Physicians Notifying Them of New Form of Tuberculosis Report.

DEPARTMENT OF HEALTH.

Milwaukee, Wis.

Dr. ....

....

Dear Doctor:—

Enclosed you will find a supply of blank forms to be used in reporting cases of tuberculosis to this office as required by state law. A supply of envelopes is also enclosed.

As you will well recognize, it is a very difficult matter for the department to combat tuberculosis in a proper manner unless it has a complete record of all cases. Furthermore, it is essential that those afflicted with the disease be educated so that they may not infect others. Many cases occurring in the poorer parts of the city need assistance of one kind and another, and if you will be kind enough to fill out these new forms in the future, the department will gladly cooperate with you and see that everything is done to assist the patient and decrease the opportunities for the spread of the disease.

I realize that some cases need no visit or assistance from the department, and that such a visit might be distasteful to both patient and yourself, but the large majority of cases are in need of some assistance.

The use of this blank will enable you to state your wishes with regard to the disposition of each case, so that there need be no friction between the department and yourself.

Thanking you for your past co-operation and anticipating a further continuance of it in this important matter, I am,

Yours very sincerely,

Health Commissioner.

P. S. A further supply of blanks and envelopes can be obtained by application to the Health Department Office.

TABLE III.

DIPHTHERIA, SCARLET FEVER AND TYPHOID FEVER IN MILWAUKEE 1900-1910.

Year.	Cases.	Cases per 100,000 population.		Deaths.	Deaths per 100,000 population.		Case Fatality.	
DIPHTHERIA.								
1900	716	247		124	42.7		17.3	
1901	483	164	Average 124	100	33.9	Average 22.3	20.7	Average 17.4%
1902	463	154		85	28.0		18.3	
1903	353	112		64	20.6		18.1	
1904	321	98		53	16.0		16.3	
1905	310	92		43	12.8		13.8	
1906	482	139	Average 197	65	19.0	Average 26.3	13.4	Average 13.5%
1907	621	177		85	24.2		13.7	
1908	494	137		70	19.4		14.1	
1909	835	225		120	32.4		14.3	
1910	1147	307		135	36.4		11.8	
SCARLET FEVER.								
1900	1726	595		70	24.1		4.0	
1901	372	126	Average 134	16	5.4	Average 6.3	4.3	Average 4.4%
1902	234	78		10	3.3		4.2	
1903	331	105		9	2.8		2.7	
1904	672	206		41	12.6		6.1	
1905	527	157		24	7.4		4.5	
1906	162	47	Average 247	11	3.1	Average 17.0	6.7	Average 6.8%
1907	215	61		20	5.7		9.3	
1908	524	145		17	4.7		3.2	
1909	1801	486		191	51.6		10.6	
1910	1852	496		76	20.1		4.1	
TYPHOID FEVER.								
1900	340	117		59	20.3		17.3	Average 24.6%
1901	205	69	Average 72	63	21.3	Average 17.5	30.7	
1902	211	70		48	16.0		22.7	
1903	198	62		54	17.1		27.2	
1904	186	57		43	13.1		23.1	
1905	351	104		68	20.2		19.4	
1906	571	165	Average [illegible]	98	27.8	Average [illegible]	17.2	Average [illegible]
1907	403	115		84	24.0		20.8	
1908	367	101		55	18.0		14.9	
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	

TABLE IV.

TABLE SHOWING DEATHS FROM VARIOUS COMMUNICABLE DISEASES IN MILWAUKEE SINCE 1900.

	Total Deaths all Causes.	Typhoid.	Smallpox.	Measles.	Scarlet Fever.	Whooping Cough.	Diphtheria.	Influenza.	Tuberculosis.		Pneumonia.
									All Cases.	Pulmonary.	
1900................	4026	59	0	36	70	46	124	*	468	373	376
1901................	3833	63	1	17	16	21	100	*	473	400	326
1902................	3797	48	1	36	10	49	85	*	395	320	384
1903................	4091	54	1	1	9	43	64	73	443	362	456
1904................	4182	43	1	16	41	6	53	36	490	428	493
1905................	4084	68	1	4	24	24	43	17	494	403	351
1906................	4632	98	0	34	11	30	65	9	472	416	530
1907................	4637	84	1	5	20	16	85	18	433	376	469
1908................	4454	55	0	18	17	35	70	35	435	377	434
1909................	4886	78	0	27	191	16	120	12	396	352	488
1910................	5199	171	0	25	76	28	135	20	530	470	494
Total.........	47821	821	6	219	485	314	944	†220	5029	4277	4801

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*Not given separately in annual report of Health Department for this year.

†Eight years only.

Figures taken from annual reports of Health Department.

TABLE V.

DEATHS FROM TUBERCULOSIS AND PNEUMONIA IN

1900-1910.

TUBERCULOSIS.

(all forms)

Year.	Deaths.	Deat po
1900	468	161.4
1901	473	160.3
1902	395	131.7
1903	443	140.6
1904	490	150.7
1905	494	147.7
1906	472	136.8
1907	433	123.7
1908	435	120.8
1909	396	107
1910	530	142

PNEUMONIA.

1900	376	129
1901	326	110.5
1902	384	128
1903	456	146
1904	493	151.3
1905	351	104.7
1906	530	153.6
1907	469	134
1908	434	120.5
1909	488	132
1910	494	132.4

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AN EXPERIMENT IN PUBLIC HEALTH ADMINISTRATION.

EARLE B. PHELPS,
Massachusetts Institute of Technology.

Read before the Massachusetts Association of Boards of Health, July 31, 1913.

The problem of board of health administration in the towns and villages is largely a financial problem. The important matters in city health work, such as the isolation and care of the sick, school hygiene, the milk supply, housing and factories, general cleanliness and the rest are all primarily due to or aggravated by the concentration of population. In the small community the control of these matters is relatively simple. Given a sufficient appropriation and a live health officer, there is nothing to prevent an ideal situation.

But the very factors which make for this fortunate situation bring with them a compensating disadvantage. There is in each such community a little work of each kind to be done; a little milk inspection, a little diagnostic and laboratory work, some plumbing inspection, a few nuisances, etc. Moreover this work, although small in amount, is of so diversified a character that its proper handling requires a certain amount of expertness in the several lines. No one will contend, I believe, that the same person can properly inspect plumbing and also examine suspected diphtheria cultures. Specialization is as necessary here as in the case of the cities, and a group of workers corresponding on a small scale to the organization of a city board seems to be the first essential requisite. The process of subdividing, however, reaches a natural limit in a group of three or four specialists and the cost of even such an organization in the case of a small town is entirely disproportionate to the needs.

It seems a logical solution, therefore, since we cannot further reduce our organization unit, to increase the size of the community unit by coöperation among several towns. This, in fact, is the only apparent solution, short of state or county control; for no one will contend, I hope, that the method prevalent in Massachusetts of entrusting the health work of the town to the inexpert hands of local physicians and business men is any solution at all. No matter with what degree of public spirit, enthusiasm and personal sacrifice such men undertake their duties, their work compares with the work of an efficient organization much as the work of the old volunteers compares with that of a modern fire department.

Let us now consider the details of an experiment in public health administration which has been built about the two principles which I have outlined here—specialization and coöperation.

The Board of Health of Wellesley had for three years previous to last fall employed a trained man, Mr. C. K. Blanchard, to give his whole time to the duties of agent of the Board. In November Mr. Blanchard accepted a position in the New Jersey State Board of Health and thus created the immediate opportunity for putting into effect a program which had been previously mapped out by Professor Sedgwick and some of the officers of the Department of Biology and Public Health of the Massachusetts Institute of Technology. This matter was taken up with the members of the Wellesley Board who were immediately interested and who later appointed the speaker general agent of the Board with power to organize a small administrative unit. This agreement was to run for six months to allow time for the extension of the idea. The funds that had been available for Mr. Blanchard's services were placed at our disposal and it was understood that department or personal funds would be used to make up any deficit.

It was realized at the outset that coöperation would never be brought about by mutual agreement among the towns. The question of the proper division of the expense and of the service would involve the whole project in an endless and fatal discussion. We were after results and we went to each town, explaining the coöperative nature of the undertaking but making a definite individual offer of so much service for so much money. There was necessarily a good deal of bargaining, and we had to meet existing conditions of finance and needs so that our financial arrangements are perhaps not quite equitable and not thoroughly businesslike. By April first six communities had accepted this service in whole or in part and later two others came in. The list at present in the order of participation, is Wellesley, Belmont, Framingham, Weston, Needham, Melrose, Winchester, Canton.

In Melrose and Canton only the milk inspection has been placed in our hands and in Winchester we merely do the laboratory examination of the samples collected by the milk inspector. In the remainder of the group we perform all the administrative work of the board of health, except that in some towns the plumbing inspection is not included in our agreement.

Each town makes a definite appropriation for the year's work and enters into a contract with the general agent for stipulated services at a fixed lump sum.

The total appropriation amounts to about $6,300 per annum. The population served is approximately:

For milk inspection, alone,	25,000 additional
For general administration (including milk inspection),	30,000
Total,	55,000

We have thus brought about the first requirement of our program and built up a community unit which is big enough to support our minimum organization.

The organization itself comprises an administrative officer, who acts as agent of the several boards, a chemist and bacteriologist, responsible for the laboratory work, a plumbing and sanitary inspector and the necessary clerical and laboratory assistants. There is also the general agent, responsible for the business relations, and matters of general policy, whose services are given to the organization by the Department of Public Health of the Institute. This is the minimum unit for efficiency. With it we can bring expert treatment to bear upon almost any question which may be raised. It is not, however, the most economical unit. By the employment of assistants at a 60 per cent. increase in cost, the output could be doubled and no efficiency sacrificed.

A central office and laboratory is maintained at Wellesley where the laboratory originally installed by the Wellesley Board has been reëquipped for its broader service. An automobile and a motor cycle, together with the telephone, make rapid communication possible. Definite office hours are maintained in the larger centers either by one of our own staff or by a town official whose duties permit him to act as resident clerk to receive complaints and mail and communicate them to the central office. To conform with the law, the various Boards appoint the members of the staff, as their agent, milk inspector, plumbing inspector, bacteriologist, etc., but the organization pays the salaries and running expenses and the agent is responsible for all results. He reports monthly to the Board in writing with a detailed account of all his work.

Culture stations are located at central points at which supplies of media and diagnostic outfits of forms, etc., and of the various state board supplies (vaccine, antitoxin, etc.) are kept. At certain of these stations also portable incubators are maintained so that throat swabs deposited previous to midnight are reported upon the next morning. Positive diagnoses for diphtheria and typhoid are reported at once by 'phone.

The laboratory with its complete equipment for diagnostic work of all kinds under the supervision of an expert diagnostician and the facilities for prompt reports upon this work comprise one of the most valuable features of the service.

The milk supply of each town is examined chemically and bacteriologically once a month. The results are reported to the dealers promptly and to the Board with the agent's monthly report. In the majority of the towns the results are also given to the press and in all cases the records are on file at the local office and may be inspected by the public. We consider this publicity a most valuable feature in controlling the quality of the milk. With it we believe we can safely do away with arbitrary legal standards. If the facts are placed before the consumer, self-protection forces the dealer to improve or drop out. Instead of trying to evade the law and looking upon the milk inspector as a necessary evil, he now comes to us voluntarily for advice and—what is more important—does what we suggest. We place little reliance upon inspection for we cannot inspect proper behavior into a milkman who has no incentive to behave. We do, however, familiarize ourselves with conditions, especially when the analysis shows them to be bad in order to properly advise the producer. We are working on the theory that the laboratory examination of milk is the primary board of health function. It shows us what we are getting. Inspection of dairies is a duty we owe to the farmer if he desires to profit by such inspection.

It was intimated at the outset that this problem of board of health administration is primarily a financial one. There is nothing new in our work; any one can do it with proper funds. The important and novel feature is to give this expert work to towns at a cost which makes it possible for them to take it up. An important matter, therefore, is the accounting. We are maintaining an up-to-date cost-keeping system and know to a penny what each kind of work costs. Even our auto mileage is charged to the various items of work and at the end of the year the costs will be assessed on our books against each town and a profit and loss balance struck, upon the basis of which the costs for another year can be definitely adjusted and new work taken on. Our purpose has been to render the service at cost with no charge for the department oversight, which Professor Sedgwick has generously provided for. At the same time the organization must be self supporting and should show a comfortable reserve for contingencies.

The work is experimental then in a financial as well as a political sense. After April first, 1914, it will remain for the towns to decide whether or not they wish to continue the arrangement. Whatever may be the outcome of that decision, whether the organization shall be enlarged to take in a wider circle, which it can do with additional economy, or shall complete its work and disband, the experiment will have demonstrated the feasibility of this type of coöperation, the satisfactory nature of the service thus made possible and the remarkably reasonable cost of this sort of expert public health administration.

Discussion.

VICE-PRESIDENT W. T. SEDGWICK: I ought to say that Professor Phelps gives a good deal more credit to me and to our department at the Institute than we deserve. It is he, as the representative of that Department, who has done all this and has made it possible. It has been his persistence, his tact, his far-sightedness, which have initiated and carried on this most interesting experiment. The rest of us have supported him and looked on; that is about all. The truth must be told.

Mr. R. N. Hoyt:[*] I think there are two sides of this very interesting problem. There is a side which may appeal to the communities that we serve, of bringing to them something from outside, something new, but we are also finding that this is twofold, it is bringing to us a great deal. In each community some particular line of work is more developed than it is in other communities. That gives us a chance to do in that community something experimental, which can be carried to the other towns, and I have found that personally very helpful. In one town we can develop milk inspection to an especially high degree. The experiments which we try in that town are very useful and can be applied in other towns. The line of publicity appeals more to one town than it does to another, and we find that developing that idea in one town, finding what really does appeal to the public, what kind of publicity brings results, we can apply that lesson in other towns. And so in many ways we are finding in this community organization, this organization which comprises several localities, a chance to do experimentation in one town that shall be applied in these other communities.

Prof. C. E. A. Winslow: I should like to say a word about Professor Phelps' paper. I cannot quote Doctor Anderson's words, but he stated, it seems to me, today the whole matter in a very complete way in one sentence when he said that the problem of the health officer, national or local, was to get enough money and then to spend it wisely. That was the effect of one of his sentences; but, of course, it is not altogether an easy thing to do. We have come during the last five years to a period of heart-searching as to the most efficient methods,—particularly of spending money for public health work.

I had an interesting experience just about a year ago in the study of the local health situation in the city of Minneapolis, to take the case of a large city. There the civic bodies became interested in an attempted reform of the health department, and called Doctor Biggs, the chief medical officer of New York City, and myself, to make a scientific management study of the health department. We studied the various activities, the control of communicable disease, facilities for hospitalization, control of the food supply and the milk supply, particularly methods of disinfection and so on, and we arrived at results which were at first very disappointing to the civic bodies, who expected an attack, or an exposure of the inefficiency of the health department. We found, without going into details, these two outstanding things: First, that Minneapolis was appropriating the smallest amount for public health service, something like 15 cents per capita. of any of the large cities in its class, against appropriations of over 50 cents for Boston, New York, Newark, New Orleans, and amounts ranging down to Minneapolis, about 15 cents. We found that the particular lines of health department activity that were most neglected there were the ones that had the most inadequate appropriations, that whereas, for example, New York was spending 5 cents per capita for school inspection Minneapolis was spending about half that amount, that while New York was spending 2 cents for infant mortality work Minneapolis was spending practically nothing for that purpose,—I mean through the official health department, and throughout that the appropriations for the most important public health activities were the ones that were the most inadequate. In the second place, we found that the health department was a department of the city council, that all the employees of the health department were appointed once a year by a committee of the council, that the ordinances were all drafted by the council. At that time they had been working for years under a milk ordinance which provided that all the milk of the city should come from tuberculin-tested cows. That, of course, made any attempt at even a milk-license system impossible, and they could not get that ordinance changed. At the time we were there, there was a serious outbreak of rabies, and a muzzling ordinance was referred to a committee of thirteen aldermen, a month before election. So that our conclusion was that although the health department was inadequate in many respects it was a great deal better than the city deserved, in view of its faulty organization and its inadequate appropriation, and that was a surprise, and threw a good deal of light on the situation to the local people.

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[*] Administrative Agent of the Cooperative Organization.

With a large city it is possible by proper legislation and proper appropriations and with the right men, to get the work done in splendid fashion, to get results such as have been obtained, for instance, in New York City, where the administration of the local health department is an inspiration to any one who can study it; but in the small town there has always been a more serious difficulty. It has been the difficulty that Professor Phelps has so well stated, that the small town cannot afford to pay for the various kinds of expert advice it needs. This difficulty is being met in different parts of the country in various ways. We have just met it this spring in New York state by a very drastic and far reaching law which abolishes the local board of health entirely, keeping the local health officer and placing him under a district sanitary superintendent, who is in turn under the state department of health. This is not a method which, from what I know of the spirit of Massachusetts, is likely to find favor in this state. It is particularly fortunate, therefore, that you have had worked out here this experiment so full of promise, so in harmony with the spirit of Massachusetts. The small town cannot solve this thing alone, and as I say, I think it unlikely that the town in Massachusetts will care to give up its powers to the state, but it can meet the difficulty by coöperation. It seems to me this idea put in practice in this way is one of the most hopeful things that has ever happened for the cause of local health administration. Ours is a period of experimentation in health organization. That title pleases me particularly. The fundamentals of public health science have been worked out in many lines now, so that they can be applied satisfactorily. We have got to experiment with organization, putting them in practice. You know they define an efficiency engineer as an engineer who is out of a job, and, of course, there is a good deal of danger in all this sort of thing. That is why the good efficiency engineers prefer to call their science scientific management. We need scientific management applied to health department organization. It is a great thing to see that it is coming. It is a great thing to see that the Massachusetts Association is carrying on its good work of leadership in this line.

DR. J. F. ANDERSON: I think that this work that Professor Phelps has referred to is really one of the most important things that has been brought out in public health work for a long, long while. The efficiency of public health work after all is a local problem. You have got to have efficient local health officers. Why, take even our vital statistics. We have a bureau of census which collects certain vital statistics, the public health service itself collects and publishes certain morbidity statistics, but after all we are absolutely dependent upon the local people for these statistics. And it is the same way whether we have a department of public health or any other federal department, after all it is a local problem, and the furthering of such work as Professor Phelps has referred to here this afternoon in my mind is one of the most hopeful indications of what we may expect in the near future.

DR. M. J. ROSENAU: I will be brief, although there is much that I am tempted to say; and I think you will agree with me that it is an act of considerable self-restraint that I refrain from discussing Doctor Anderson's splendid paper, which to me was very much like a twice-told tale admirably told. You may not know that for twenty years I participated in many of the activities that he told us about this afternoon. While I am on my feet, however, I want to say a word about the remarks that Professor Phelps has favored us with this afternoon. I do not agree with what Professor Winslow has said, that Professor Phelps has chosen an attractive title to his paper. I do not believe that this is an experiment, I believe it is an accomplished fact, and I believe it is one of those things in coöperation which is not only going to extend throughout Massachusetts but neighboring and distant states and foreign countries. We all know that the weakest link in the sanitary chain is the country, and it is the country that must be reached in order to prevent infection spreading and flowing to the city. One cannot go to any meeting, whether medical meeting, sanitary or hygienic congress, philanthropic association, or uplift society of any kind today, at which one does not hear that keynote word, coöperation. We almost grow weary of the reiteration and sometimes feel that it has been overworked. But after all it is necessary: coöperation, not only between Federal Government and state, and between state and local authorities, and between local authorities and the people themselves, but coöperation between all the agencies concerned, one and another interlocking in helpful ways. It must be perfectly evident to anybody who is at all familiar with the situation, that the real work in preventive medicine rests with the people themselves, guided by the local health authorities; furthermore, that sparsely settled districts and small communities cannot effectively and efficiently apply all the modern scientific methods, which are sometimes expensive and cumbersome, and which requires experts that cannot be supplied by each little township. It, therefore, requires the kind of coöperation and concentration of effort which Professor Phelps has so ably and so well described, and which he has so efficiently put into effect. The principle is not new; we have had coöperation in Metropolitan water supplies, in sewage disposal, in school, police, fire and other things. It now is time to apply the same idea to health. Professor Phelps modestly says that the credit and honor belongs to Professor Sedgwick. Perhaps it does. Professor Sedgwick in turn turns it over and says it belongs to Professor Phelps. Perhaps it does. So far as I am concerned, it may belong to both of them, for I think there is enough in the proposition, that is, enough honor, for all.

A MODEL HEALTH DEPARTMENT.

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It is a rare honor to be invited to address such a distinguished group of gentlemen, many of whom occupy the most important civic positions in the various cities of this great State.

The subject of my paper is "A Model Health Department." In some respects this title is not a suitable one as it has been pointed out that the word model means a small imitation of the real thing and certainly that is not the type that is needed for a health department. As I conceive it, a model health department is one that is giving its city the maximum health protection at the lowest possible cost.

It is indeed remarkable to consider the wonderful development of Health Departments during the past decade. It would be difficult to estimate the number of such departments which have awakened from their long sleep and which have commenced to show marked activity in their life-saving and comfort-giving functions. Many are yet merely rubbing their eyes and still yawning, some unfortunately are still deep in the dangerous oblivion of unconsciousness. The indications are that shortly even the laggards will have to arouse themselves and the reason for this is the wonderful and astonishing demand of the man on the street that he and his family be protected, not only from fire and from thugs, but from the invisible array of microbes which is lurking here and there to do him ill if the opportunity arises. The function of the Health Department is to eliminate these opportunities. It is not possible for a citizen to attend to the safe-guarding of the health of his family himself. He pays taxes for protection and adequate protection should be his.

It is idle to point out the well recognized fact, oftentimes disregarded that the first necessity for a proper health administration is a properly trained health officer, who shall not be removed unless for a failure to discharge his duties.

The high degree of uncertainty of tenure of office acts as a strong deterrent to many who would like to enter the field of public health work. We might well ask why this high degree of uncertainty of tenure of office? The answer is, of course, easy to find and is essentially incorporated in the words "party politics." It is easy to hurl criticism at the present frequent wholesale change in the city offices which are apt to occur at times when there is a change of party. It must be realized, however, that this is largely due to the whole system of government and the Republican President who appoints Democrats to important places in his cabinet, is considered by many to be unwise, irrespective of the ability of the men selected.

Occasionally, although rarely, we see health officers, so securely entrenched in their position that there is much danger to those who attempt to oust them.

Granted, then, that there should be certain tenure of office, the second and equally vital thing is that the incumbent of that position should be trained in the sanitary arts. The wonderful development of the sanitary arts makes it impossible for a person without special training to serve as an ideal health officer. Many health officers without special training have, and are giving their cities a wise health administration. Their school has been largely the school of experience, a very important school to be sure, but a thorough understanding of the real principles involved in disease prevention is essential. Some of the most dramatic things that a health officer can do, such as abating some prominent nuisance, have oftentimes but little effect on decreasing sickness or preventable deaths. The work that is really going to produce these desired results is oftentimes of a very silent nature. The fighting and curbing of an epidemic is work that is important and interest-impelling, but the quiet, sane and careful routine work which will prevent a disease from assuming epidemic form is the real kind of work that a trained health official should do.

It is important to note that many medical schools, and technical institutions, are now giving special training in public health work, and at least two schools in this country are now giving the degree of doctor of public health to students who qualify in special courses.

In order to get the right man for the health commissionership of a city, it is frequently necessary to go out of the city. This is a very unpopular step in many places and it requires a courageous Council or Mayor to take it. The question that comes up when a health commissioner is to be appointed is to get the right man, even if he lives elsewhere. You may have noticed that recently the Mayor of Boston has advertised for a man to be chairman of the Board of Health of that city, and it is possible that he will eventually appoint some one from outside to fill the position.

Of course a trained man, without the necessary tact, firmness and fearlessness, may be worse than useless. These characteristics are essential and make the problem of getting the right man a difficult one.

In an ideal department, where the right man can be assured, it is necessary that he be not tied down and fettered with interferences in the execution of his duty. Too frequently we find Boards of Health composed of persons who oftentimes have little or no qualifications for such a position, and the Board instead of being an advisory board for the health officer to consult with, is the ruling board, which outlines the work for the health officer, settles questions which the health officer should settle himself, and which generally interferes with the proper health administration of the city. Personally, under the model ideal conditions, I should like to see many Boards of Health abolished and the health officer made directly responsible to the Mayor or to the Commissioner of Safety, if there be such an individual.

The health officer should be a man who can be trusted and if such a man is chosen, he should not be hampered with boards or committees. Of course it is not possible to have a man devote his full time to health work, which he should always do in larger communities, if he is going to be paid a mere pittance. The salaries paid in many cities for the health officer and his necessary associates are disgraceful. Is there any city official more important than the health officer? I do not believe so. If this is agreed to, then why should he not be paid a fair salary. It is certain that the men who would be willing to undertake this position, oftentimes cannot consider it for a moment on account of the small remuneration that goes with the work.

It is not merely a question of an adequate salary for the health officer, it is also very largely a question of adequate appropriation to enable him to carry on the work in a proper manner. The health officer should be largely executive and should have sufficient assistants so that he will not have to waste his time attending to matters which can just as well be looked after by some subordinate.

Fire and police protection is most necessary and costly. Is not health protection worth more than is now oftentimes spent for it! It is positively sickening to see a well-meaning but ignorant council ruthlessly cut off a few hundred dollars from the Board of Health appropriation, when this money was to pay the salary of an educational nurse for the prevention of infant mortality, or tuberculosis work. Economy and a low tax rate is the cry, and amongst other city departments, the Health Department's estimate is trimmed. But with this difference. The total amount asked for by the Health Department is always very much smaller than that asked for by the Police, Fire and Public Works Departments, and a cut of the estimate of the former may be a very serious thing. On the cover of the Monthly Bulletin of the New York City Department of Health is the statement that within certain natural limitations a community can determine its own death rate. That is to say, public health is purchasable.

Too frequently there is the false belief that the real serious problems that beset the large and crowded cities, are not present in the smaller places. This is untrue. The problems in large cities are so great that their very magnitude impels and commands attention. In the smaller places this is not so, and it will only be through the intelligent studies of the Health Department that the existing evils will be sought out and remedied.

True economy is a good thing but false economy is a very dangerous thing.

The model Health Department will know what things to emphasize, what things to pay some attention to, and what things to leave undone.

Is it not easy to see that it has to be largely a matter of choice with a health commissioner what he is going to do? He has a certain amount of money and certain other resources. How shall he spend this money and how use his staff? Here it is that an exact knowledge is necessary. Certain kinds of work done by Health Departments have little or no sanitary significance, and nuisances, for example, are of minute sanitary significance, and the abatement of nuisances in many instances has no appreciable effect on the public health. It would be a dangerous policy for a Health Department to pay a great deal of attention of nuisances and little to communicable diseases, which have no connection with the nusiances. Do not let it be thought that I am desirous to have the nuisance work overlooked, on the contrary, this work is very important, and if it contributes to the general comfort of the citizens it is of immense value. Public comfort is almost as important as public health, and it is natural that it should seem more important to the public. This is really due to the fact that public comfort and public health are mixed up and not well differentiated.

The model Health Department will be properly organized. It is certain that the Boards of Health of many cities at the present time have an ineffective organization. This is partly due to the fact that with the marked development of sanitary science and the consequent addition to the work of the Health Departments, that the growth of the department has not been made as orderly as it should be, and we find instances where the organization is such that certain phases of the work which are of minor importance are given too much emphasis, while other important phases are somewhat neglected. The importance of health laboratories, for example, is a subject which in many places has been sadly neglected. It cannot be expected that the small communities can afford to maintain a laboratory of their own and it is for these places that the State Board of Health has its State Laboratory. The benefits to be derived from a well conducted health laboratory are great and I have in mind certain small cities of some twenty to fifty thousand inhabitants which maintain their own laboratories with great success and they are of much value to the citizens.

Co-operation between the Health Department and other city departments is another important point which unfortunately is oftentimes found to be lacking and the model Health Department will naturally have good relations with many other departments. It should be particularly in touch with the school authorities, not only on account of the fact that both health and school authorities are very closely interested in communicable diseases, but because of the fact that both of these departments are interested in educational work. Within the past few years Health Departments have assumed a distinct educational character, and in some of the largest departments of health in the country we find special divisions for educational work on disease prevention amongst the people.

Again, co-operation with the police department is very essential. In foreign countries, notably Germany, the police attend to much work for the Health Department, particularly in connection with the abatement of nuisances, many of which have little or no health significance. It has even been suggested that general outdoor nuisances, inspection, etc., be turned over to the Police Department so that the Health Department may be relieved of a great deal of work which will bear but little fruit as far as the prevention of disease is concerned, so that they may already take up in greater detail such important questions as housing, which undoubtedly is a very important phase of public health work. Similarly in many places the Health Department is being relieved of the work of garbage collection and disposal, and plumbing inspection. This is as it should be, although, of course, the Health Department necessarily should be in close touch with those departments which are tending to these important branches of civic work.

Some few years ago I made a study of the annual reports of the Health Departments of many of the smaller cities of this country, and found that they were in many instances in no way comparable. The Association of the Boards of Health of Massachusetts at the present time as a result of a suggestion made by me, has a special committee at work drawing up a standard form of report of the Health Departments for the cities of that State. This will in no way interfere with the proper presentation of the special problems affecting each city, but will make it possible to have in proper form the same general information from the various cities of Massachusetts, and in this way health officers will be able to measure the success of their confrères in other communities and they will receive a stimulus in this manner to attack their own problems. This Massachusetts committee is considering very carefully the question of the financial statement so that the cost side of the various activities of the Health Department may be properly demonstrated. I hope to see the time when the Health Departments throughout the country will use the same general methods for the presentation of their reports. To sum up then, the Health Department of a modern city should be in charge of a competent trained sanitarian who shall be adequately paid and whose tenure of office shall be made certain. He should be granted a fair appropriation to enable him to carry on his work. He should be relieved as much as possible from all work that by right should be attended to by the police, public works and other city departments. He should be properly armed with reasonable laws capable of enforcement. He should have the close co-operation of the Mayor, the Council and other city departments and he should have the necessary sanity, and yet be firm and fearless, to conduct his work in a proper manner. There is need in many places for a rationalism in public health work, and there is a growing tendency to discredit certain kinds of public health work which have arisen largely through the over-emphasizing of certain points.

Another very important thing for a health officer who desires to keep thoroughly posted on the progress which is being made throughout the civilized world in matters of sanitation, is that he should be a member of some of the important public organizations in the country which are devoting their attention to public health problems. In this connection every health officer should belong to the American Public Health Association. This organization embraces the United States, the Dominion of Canada, the Republic of Mexico and the Republic of Cuba and many of the leading sanitarians of the country are members. The Association holds an annual meeting and publishes a monthly journal, the American Journal of Public Health. I regret to say that a very large number of health officers do not belong to this organization. The membership of this organization should be paid for by the city, and as secretary of the American Public Health Association, I extend a hearty invitation to the health officers of New York to join. The benefits which they will derive are difficult to overestimate. Each city should send at the city's expense their health officer, and if possible, some other important officer in the Health Department to the annual convention. This procedure is a common one with the chiefs of the Fire and Police Departments. There is no reason, in fact there is every reason, why the chief of the Health Department should be enabled to attend the meeting of this important Association.

You, gentlemen, by your presence here to-day, emphasize your belief in the value of coming together to discuss the various problems which beset you. You realize the great advantages that have come to you through this annual convention, and therefore it needs no argument on my part to point out the great advantages that will arise to your various communities if they are represented by an intelligent delegate or group of delegates. I know of no better way at the present time that the Mayors of the cities can win the admiration and respect of their citizens than through a live interest in the public health movement.

THE NEED FOR A MORE GENERAL CO-OPERATION BETWEEN HEALTH AND POLICE DEPARTMENTS

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THE NEED FOR A MORE GENERAL CO-OPERATION BETWEEN HEALTH AND POLICE DEPARTMENTS.

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Public health authorities are gradually waking up to a realization of the fact that much of the work that they have done in the past, and are in a large measure still doing at the present time, has little sanitary significance. Some health departments have already been successful in their efforts to have the work of plumbing inspection and the handling of the refuse of the community turned over to other departments of the city government. This is as it should be. By transferring such work over to those city departments with which it is naturally connected, health departments can direct their energies, in a large measure, to true health work; that is, to work of such a character, that it brings about the results that the health department is striving to attain, namely, the elimination of unnecessary sickness and the prevention of death from preventable causes. There is a growing tendency on the part of some sanitary authorities to divert a large part of the work of so-called general sanitary inspection to the police department. Such work takes up much of the time of the inspectors of the health department and constitutes one of the largest divisions of the department's labors. Germany in particular has led in this respect, and the good results obtained in certain cities in that country have been most marked.

It has been well pointed out by Chapin, Jordan, and others, that the greater part of sanitary inspection as now carried on has either no public health significance at all, or if so, to a very slight extent. Greater benefits for the community could be brought about by the sanitary authorities, if they were free to direct their resources and energies to an attack on some of their large and pressing problems. These problems have only been nibbled at in many cities, and in some instances have been left absolutely untouched; nevertheless, many of them give promise of beneficial results that are impossible of attainment by ordinary time-consuming sanitary inspection and nuisance work.

It must not be forgotten, however, that certain nuisances, which have been considered of little or no sanitary importance by some, have been pointed out by Levy and others to have real sanitary import, and that a growth of weeds, for example, on a city lot, while not dangerous on account of the weeds, may hide deposits of human wastes, which must naturally be considered of very grave danger, and furthermore, that such conditions may give rise to places where insects may both develop and receive infection, which they can carry and in this way infect foods.

Many conditions existing within the limits of a community are objectionable; they offend our æsthetic tastes, and are contrary to decency. The police department, which is established to look after law, order, and decency of a community, would be a more suitable department to attend to such work than the health department, for the average nuisance is much more likely to be of police than of health concern. There are many advantages of the scheme proposed which readily suggest themselves. One of the most important arises from the fact that at the present time, health departments are largely undermanned; they cannot make the necessary frequent inspections of their districts. It is recognized that the amount of inspection of a district increases directly the number of nuisances discovered in that district, and at the same time reduces the number of new nuisances which would be created were it not for the frequency of inspections. Another obvious advantage is to be observed in the size of the districts or beats covered by the police, as compared with the size of the districts covered by the sanitary inspectors. It need not interfere with the efficiency of the police force to make a regular inspection of back yards, vacant lots, etc., in their respective territories, a certain number of times a year, and the very fact that they are policemen, and not sanitary inspectors, would have a much greater effect on those who were accustomed to violate the city ordinances. Fewer nuisances would be created, and existing nuisances would be abated more rapidly.

Most nuisances arising from the dumping of rubbish on vacant lots are given birth under cover of darkness. Policemen are much more likely to discover such violations of the law at the very time of their perpetration than sanitary inspectors. With the police acting as general inspectors, there is both day and night inspection.

It is well recognized that the amelioration of a so-called insanitary condition is often very difficult to bring about through the Health Department. This is because of the difficulty, or even impossibility, of proving to the satisfaction of the court that the insanitary condition was capable of giving rise to disease. Reinspection would be an easy matter, and would not consume much time. The patrolman would not have to make a special trip to see that the order had been complied with. His ordinary patrol work would make it both possible and easy for him to visit the place every day, if necessary, and this would be an added incentive, in many instances, to the person responsible, to clean up or make the desired change.

It would not take a district long to learn to expect this constant inspection, and as a result the number of nuisances should quickly decrease, and the ideal of a clean city would be much nearer than before. The police already have to deal with the abatement of nuisances to some extent, ordering the removal of snow from sidewalks and enforcing the anti-spitting ordinances.

Special training on the part of the patrolman is not a requisite in order to enable him to do outdoor general sanitary inspection work. Moderate intelligence is all that is required, and in the event of a patrolman discovering any condition that might actually produce disease, or about which he was in doubt, he could report his finding, through his station, to the health department, which would have its district inspector visit the place and make an investigation.

Noise nuisances, which are worthy of considerable attention, should also be in the hands of the police department.

Simple forms of reports should be used by the patrolmen for each inspection. If the conditions were satisfactory, there would be no need for anything more than the address, date, the O. K., and initials. These reports should be kept in special note books. It would not take long to educate the public to a knowledge of the fact that the police department was the one to complain to in case of nuisance. Officers would doubtless receive complaints while on their beats, and telephoned or written complaints could readily be assigned to the patrolman of the beat in which the nuisance was supposed to exist.

Cases of failure to abate nuisances could be dealt with summarily by the police department, and would not have to go through the long, and at times uncertain process that seems to be essential in many places to cases prosecuted by the health department.

Many cities already give the police department, in the laws and ordinances under which it operates, full power in the matter of prevention and abatement of nuisances. Where this is not the case, it should be comparatively easy to have the necessary power conferred on the police department by ordinance, if the city charter permits.

ADVANTAGES.

The four main advantages of such a plan as outlined above may be summarized as follows:

(1) Increase of efficiency of public servants in the amelioration and prevention of nuisances, and a resulting cleaner and more decent city.

(2) Health department able to devote more of its time to true health work, and to bring about healthier community.

(3) The development of coöperation between police and health departments.

(4) No added cost to city.

METHODS OF OTHER CITIES.

In order to discover what was being done in the large cities of this country along this line of police inspection, the following questions were submitted to the chiefs of police of the twenty-seven largest cities in the country.

(1) Does the police department make any general inspections of the city by its patrolmen for nuisances, dirty lots, cellars, etc., or is this work done entirely by the health department?

(2) If done by the police department, how many inspections are made each year of each piece of property or premise? Are records kept showing the number of such inspections per year? Is it done in the regular rounds of the patrolmen?

(3) What is the procedure in cases where violations of the city's ordinances are discovered?

(4) Are you in favor of having the patrolmen do this general inspection? Give reasons for or against.

Twenty-one answers were received. The results of this inquiry are here given. The opinions of the various police chiefs are, of course, the opinions of those in office at the time of this study. (May, 1911.)

New York.

Section 312 of the Greater New York charter provides as follows:— "The Police Commissioner upon the requisition of the Board of Health shall detail to the service of the said Department for the purpose of enforcing the provisions of the sanitary code, and the acts relating to tenement and lodging houses, not less than fifty nor more than one hundred suitable officers and men of at least five years experience in the police force. At least thirty of the officers and men so detailed shall be employed exclusively in the enforcement of the laws relating to tenement and lodging houses. These officers and men shall belong to the sanitary company of police, and shall report to the Board of Health. The Board of Health may report back to the Police Department for punishment, any member of said company guilty of a breach of order and discipline, or of neglecting his duty, and thereupon the Police Commissioner shall detail another officer in his place, and the discipline of the said members of the sanitary company shall be in the jurisdiction of the Police Department, but at any time the Board of Health may object to any member of said sanitary company on the ground of inefficiency, and thereupon another officer or man shall be detailed in his place."

These men are practically sanitary inspectors with full police authority.

The various duties of this sanitary squad are as follows: enforcing sanitary inspectors' notices; making inspections on sanitary inspectors' notices; investigating citizens' complaints; inspecting manure, ash and garbage dumps, and offal dock; enforcing isolation of contagious diseases; destroying animals condemned by veterinary surgeons of the department of health; and making arrests for all violations of the sanitary code.

Chicago.

Here inspections are made entirely by the health department. The general superintendent of police is not in favor of patrolmen doing inspection work "for the reason that it takes up too much of their time, and their services are required in the more important work of protecting the lives and property of citizens; also for the further reasons that such inspections should be made by persons skilled in the laws of sanitation."

St. Louis.

The chief of police reports that his department works in conjunction with the health department in the abatement of nuisances. Patrolmen on their rounds are on the lookout for insanitary conditions, and all conditions of this kind which are found are at once referred to the health department, which presumably makes a further inspection. No records of the number of inspections are kept by the police authorities. The work is looked upon only as a matter of daily routine. No specific time is designated for this particular work. Prosecutions are made through the health department. The chief of police is in favor of having the police department work with the health department "in regulating sanitary conditions, as the officers are certainly more familiar with their respective beats than are the health inspectors."

Boston.

In this city "where nuisances, dirty cellars, etc., come under the observation of the patrolmen, the cases are reported to the Board of Health." No forms are used in connection with this work.

Baltimore.

At the request of the health commissioner a general sanitary inspection is made yearly by the officers of the police department. The health department is furnished with the reports of this inspection and has to see that the law is enforced.

The police marshal believes that his department is "better equipped to make the yearly sanitary inspection than any one else."

San Francisco.

Patrolmen report anything they observe in relation to dirty lots, nuisances, and cellars, etc., but no regular inspections are made except in emergency cases. The chief of police does not approve of the police "acting as inspectors, for the reason that this is not police duty."

Detroit.

In this city a detail of patrolmen in uniform, known as the sanitary squad, under command of a special captain, do the work of inspection for sanitary conditions. They coöperate with the board of health. Each member of this squad has a district which he takes care of, going over it as often as possible. Records are kept of all violations found, and the legal side of the question is in the hands of the police department.

Washington.

The police department coöperates with the health department in reporting all nuisances, dirty lots, alleyways, streets, etc. They do not take into consideration, or enter, private premises. No special times are set for such inspections. The superintendent of police is in favor of the members of the police force reporting all such cases, but is not in favor of members of the police force taking summary action. In the words of the superintendent: "That is a matter which should be handled by the Health Department alone. The Police Department should be free from the exercise of any duties other than those looking to the protection of life and property, the suppression and detection of crime and the preservation of the public peace."

Jersey City.

"It is the duty of the officer on post in his regular rounds, to make an inspection with a view to locating nuisances resulting from dirty lots, cellars, etc., and to submit a report of such to his commanding officer, who in turn forwards it to the Health Department. A Health Inspector then makes a further inspection."

The chief reports that this method works out very satisfactorily in this city, and that in his opinion it is a practical way of handling the matter.

Minneapolis

General inspections on the part of the police department for insanitary conditions are not made in this city. Any cases coming under the special notice of the patrolmen that demand attention are promptly reported to the health department.

Providence.

The procedure in this city is identical with that of Minneapolis. The acting superintendent of police states that he is not in favor of having police inspection of nuisances, as he considers that it belongs to the board of health.

Indianapolis.

In this city, on or about the first of May, the patrolmen on day duty make a general inspection of all alleys, back yards, out-houses and vacant lots. These inspections are made in the regular rounds of each patrolman. Records are made of all insanitary conditions found, and the property owner or agent is served with a notice giving him ten days to clean up and abate the nuisance. This inspection is only made once a year and is in the nature of spring cleaning. The superintendent of police is "heartily in favor of having the patrolmen do this work, as it quickly adds to the general health of the city, and to its cleanliness and beauty, and on account of its economy, does not interfere with the regular work or efficiency of the patrolmen, and gives them a chance to investigate other conditions for the betterment of the service and the good order of the city." It takes the police department one month to accomplish the necessary work.

St. Paul.

The chief of police writes as follows:

"Patrolmen are required to report to their stations any nuisance, dirty lots, etc., found on their respective beats. No records are kept showing the number of inspections. Parties owning or renting property where a nuisance is found are instructed to clean or have same cleaned at once. If they fail to comply within a reasonable length of time, a warrant is sworn out by the officer for their arrest."

Kansas City, Mo.

Patrolmen on post make reports of all insanitary conditions which may come under their notice. These reports are forwarded to the health department. These inspections are not made at any special time but go on from day to day, "as the occasion may demand," and are made by the patrolmen on their regular rounds. The abatement of nuisances is entirely in the hands of the health department. The chief of police is in favor of having patrolmen on post make these general inspections.

Rochester.

General inspections for nuisances, dirty lots, cellars, etc., are not made by the police department. However, both police and health administration is under the department of public safety, and the police, incidental to their other duties, report all such conditions and assist in remedying them. Records are kept by the police department of all insanitary conditions found by the patrolman. The chief of police is in favor of the patrolmen doing the work of general inspection, "as experience has shown that their commands and orders are more promptly complied with than those given by Lay inspectors."

Los Angeles.

In this city all members of the police department are sworn in as deputy health inspectors and do a great deal of inspection work for the inforcement of health laws where the locations are of such a nature that the offending parties can be prosecuted. Where the insanitary condition is of such a character that it demands an inspection by the health department, that department is notified and attends to the further steps necessary to obtain the abatement of the insanitary condition. No records are kept of the reports made by the officers, as the force is restricted to a limited number of men and cannot afford to put a man on clerical work.

Pittsburgh.

No general inspections for nuisances, dirty lots, cellars, etc., are made by patrolmen. This work is done by a special "sanitary division" of the bureau of health, which has no other duties. Police officers, however, supplement the health department service by reporting all infractions of the law coming to their notice to the sanitary division of the bureau of health.

Cleveland.

There is no coöperation between the police department and the bureau of health, the chief believing that sanitary inspection is clearly "the duty of the Health Department, and the Police Department has all it can do to properly attend to its own duties."

Newark.

The police department does not undertake special sanitary inspection. Police officers, however, are required to report all violations which come to their notice. The chief is not in favor of having patrolmen undertake special sanitary inspection for the same reasons as given by the chief of police of Cleveland.

New Orleans.

Police officers report any violations of the sanitary code that come to their notice to the board of health.

Cincinnati.

Sanitary inspection is in the hands of the health department.

REVIEW AND RECAPITULATION.

The chiefs of police of five cities were opposed to any sort of coöperation between the departments on inspection work. Eight were in favor of coöperation and of having sanitary inspection work performed by the police department. It will be noticed that the amount of inspection work done and the methods employed vary considerably in the different cities.

The sanitary squad system is employed in New York and Detroit, although in the former the policemen are under the health department as far as the direction of their work is concerned. In Pittsburgh the sanitary squad is merely a division of the health department.

The common practice in the majority of the cities that replied consists of a single report to the health department of any condition that the patrolmen come across, which they consider should be looked after. This implies no special inspection to find such conditions. It is necessarily inadequate, and cannot be accepted as in any way taking the place of the thorough inspection that should be made.

A temporary intensive coöperation exists in Baltimore, Indianapolis and Los Angeles, where the police department assists the health department in conducting an annual spring cleaning. This works satisfactorily but only serves a limited purpose and implies that as soon as it is over, the people are at liberty to again commence their protracted collection of rubbish and filth, which in a year's time will be cleaned out and removed. None of these plans can be considered in any way as satisfactory as a constant inspection would be. Regular inspections should make spring cleaning unnecessary. The method of New York and Detroit in maintaining special sanitary squads, while admirable in many respects, is necessarily very expensive and cannot be considered economical for most cities.

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TRANSACTIONS

Paper No. 1272

THE ABSORPTION OF OXYGEN BY DE-AERATE WATER.

By Earle B. Phelps, Assoc. Am. Soc. C. E.

With Discussion by Messrs. W. E. Adeney and Earle B. Phelps.

The Report of the Metropolitan Sewerage Commission of New York, dated August 1st, 1912, and recently issued, contains, among othe interesting material, a Report by Dr. W. E. Adeney, in which especia attention is given to the subject of re-aeration of polluted tidal waters Dr. Adeney's views and conclusions are in many respects directly contradictory to those which William M. Black, M. Am. Soc. C. E., Colonel, Corps of Engineers, United States Army, and the writer reached after a study of this problem, in connection with New York Harbor, and fully stated in a report to the Board of Estimate and Apportionment of New York City, published March 23d, 1911. As this last-named report did not have a wide circulation, and as the matter under discussion is one of great importance, not only in the case of New York Harbor, but in all similar situations, it seems appropriate at this time to consider the facts and the conclusions that have been drawn therefrom by various workers.

Dr. Adeney made the first important contribution to this subject in his well-known experiments undertaken on behalf of the British Royal Commission on Sewage Disposal. His results are fully set forth in Appendix VI of the Fifth Report of that Commission.

He describes experiments, with glass tubes 6 ft. long and ¾ in. in internal diameter, in which he exposed de-aerated water under varying conditions, and, at the expiration of stated times, withdrew samples from various depths and submitted them to analysis for dissolved oxygen and nitrogen. Both sea water and distilled water were used. He found that, with either kind of water, mere exposure of the upper surface to the air resulted in practically negligible re-aeration in the lower depths. He reported a tendency toward accumulation of the dissolved gases in the upper layers, which was greater in the distilled water than in the sea water, under these conditions. He next closed the top of the tube, introduced a small tube just below the surface of the water, and, by suction, caused a slight current of air to bubble through the top layer of water. This led to a slightly greater absorption on the part of the distilled water. In the case of the sea water, however, this method of procedure resulted in a fairly rapid absorption of oxygen and of nitrogen, and the quantities of these gases found at various depths at the conclusion of each experiment showed a tendency toward uniform distribution.

Dr. Adeney refers to this phenomenon as the "streaming effect", and identifies it with a similar effect obtained by Huefner under quite different circumstances. He adduces evidence, although inconclusive, that Huefner's theory of a direct streaming of the liquid, brought about by difference in specific gravity, is not tenable. He did not investigate fully the cause of the streaming effect, but believed it might be due to:

> "* * * minute dust particles, or by other centres of condensation, possibly of an electrical nature, carried by the air current and being taken up by the water together with the gaseous constituents of the air, and that these bring about in some way a sufficient density of the dissolved or condensed gases to render it possible for them to be drawn gravitationally downwards through water."*

The previous passage of the air through one tube of water destroyed to a large degree its power to bring about this streaming effect in a second tube, while the power was completely lost by passing it twice through water, thence into a third tube. Dr. Adeney suggested that the ions, or dust particles, or whatever may be the exciting cause, were removed by such treatment.

Col. Black and the writer showed by experiments with dyes and by determining the amount of evaporation resulting from the passage of dry, or partly dry, air into a tube of water, following Dr. Adeney's technique, that this streaming effect, so-called, was caused by a streaming of water currents. These currents are caused by a creased specific gravity of the salt solution following evaporatio the water from the surface layer. This explains also the e of using two or three tubes in series, and the absence of any mat streaming in fresh water. In the latter case, a slight tend toward streaming was observed, and, without further investigat this was ascribed to a slight lowering of the temperature at the face, due to evaporation, and the consequent increase in the den of the surface layer. Undoubtedly, also, the increased density res ing from the solution of atmospheric gases is a factor, as shown Huefner. Although Dr. Adeney in his first report claimed to h disproven the theory of circulating currents of water, the explanati of this matter by Col. Black and the writer has been tacitly accept by him in his report to the New York Commission, so that there ne be no further discussion of the theory involved. The real point at iss is indicated in the following statements:*

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*British Royal Commission on Sewage Disposal, Fifth Report, Appendix VI, p. 64.

> "It is equally evident from these experiments that whatever m subsequently be discovered to be the true cause of the streaming, i effect in large volumes of sea or river water under natural conditio must be of great importance, and of such dimensions that the effe of ordinary diffusion may, in comparison, be entirely neglected."

Col. Black and the writer state:†

> "In practice no such results would be observed, since the uppe layers of an estuary are always somewhat fresher than the lower."

This latter statement, Dr. Adeney says, has no real foundation i fact. In this connection, reference to the New York Commission' report‡ will be of interest. Here is shown the condition of the wate at The Narrows, as regards both dissolved oxygen and salinity or percentage of sea water, at seven different stages of the complete tidal cycle. A distinct stratification is shown in each instance. From the surface to the 20-ft. depth there is an average increase of about 6% of sea water. In the case which shows the greatest uniformity throughout the depth, there is more than 2% increase. Moreover, the condition at the Narrows is less favorable to the contention of Col. Black and the writer than the majority of the cases shown in the diagrams which follow. At the mouth of the Hudson, the gradient ranges from 6 to 8% of sea water in 20 ft., and in the upper Hudson, at Mount St. Vincent, it is normally more than 10% in the same vertical distance.

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* British Royal Commission on Sewage Disposal, Fifth Report, Appendix VI, p. 64.

† Report of Col. W. M. Black and Prof. Earle B. Phelps concerning The Location of Sewer Outlets and The Discharge of Sewage into New York Harbor, 1911, p. 52.

‡ Metropolitan Sewerage Commission of New York, 1912, p. 449.

There seems to be, therefore, sufficient "real foundation in fact" for the assertion that stratification does exist, and that there is, therefore, no such vertical circulation of water from top to bottom, as Dr. Adeney found in his tubes, which were initially at a uniform concentration. If further foundation in fact be required for this almost self-evident proposition, reference may be had to the work of Morton F. Sanborn, Assoc. M. Am. Soc. C. E., on "The Distribution of Sea Water in the Charles River Basin."* As a result of a year's study, with almost daily examination of the vertical distribution of sea water in various parts of the Charles River Basin at Boston, Mr. Sanborn found stratification to be so persistent that the most severe storms produced only a temporary uniformity, even in the upper 20 ft. of the water, and that, after the cessation of such storms, stratification was re-established. The analytical evidence is direct and positive, and rests on no theory. The streaming effect which depends on the presence of more dense layers above those of less density, is impossible in waters that show increasing concentration of salt with increasing depths. These conditions exist in the cases that have been cited; therefore, the phenomenon of streaming does not and cannot occur.

Dr. Adeney's further suggestion that the sewage matters are concentrated in the upper layers is obviously true, but beside the question. We are considering the rate of absorption of dissolved oxygen by a polluted water, under the restriction that the dissolved oxygen content shall not be reduced below a certain specified amount. This value, if properly determined, will limit the amount of sewage which may be received into the water in question, under the restrictions imposed. The most favorable assumption that can be made is that the sewage is uniformly distributed. This, in other words, will give a maximum permissible pollution. If, on the other hand, we assume a concentration of pollution in the upper layers, then either the amount of permissible pollution will be decreased in proportion to this decreased volume of water available, or the conditions at the surface will be reduced below the assumed standard. Such a concentration of sewage near the surface would result in a greater average rate of oxidation than if there were uniform distribution of the same quantity of sewage, but it is not the condition of maximum re-aeration.

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* *Engineering News*, March 10th, 1910, p. 272.

Dr. Adeney next refers to the experimental technique by which Col. Black and the writer determined the diffusion coefficient. He first points out that that coefficient bears no resemblance to the one determined by Huefner, and believes that our series of ascending values with increasing temperature are due to a streaming effect, because of failure to take extreme precaution in preserving the purity of the water used. With regard to the first point, the apparent discrepancy is merely one of units used in the formula. The exact definition of a complicated coefficient of this kind cannot be simply made, and the reader is referred to the original paper (page 89) for the definition of the coefficient and the units in which it is stated. It would be a laborious matter to convert Huefner's coefficient to these units, and the magnitude of the experimental work was so much greater than his, and, in the writer's estimation, the method of experimenting was so much more reliable, that no attempt has been made to recompute the results in other terms. The form in which Col. Black and the writer have derived it is most favorable to practical application to the problem in hand.

As for the general accuracy of the analytical work, the results must speak for themselves. It would seem that Dr. Adeney's statement, "That the results obtained by these observers do not represent the true co-efficient of diffusion of oxygen in water becomes evident on carefully examining them" (page 83), and his further statement that these results have "no resemblance nor relationship to the true co-efficient," might have been accompanied with more explanatory matter for the benefit of those less familiar with the problem. Col. Black and the writer in their report give a plot, Fig. 1, showing the results of 114 tests made throughout a considerable range of temperature. Dr. Adeney quotes from page 94 of that report as follows:

> "The values are somewhat scattering, and a closer analysis indicates that some unknown factor is involved. Exceedingly concordant results are readily obtained upon any one day, while upon the following day another group of concordant results will be obtained differing from the first. Barometric corrections were later applied without relieving the situation."

From this statement, Dr. Adeney concludes that our values have been arbitrarily selected, and will give misleading results. The plot, Fig. 1, shows the general character of the errors that have been referred to. There are admittedly imperfections in the process, and the results are not of extreme scientific accuracy. For this reason, the work, which was originally carried out as a contribution to pure science, was not published as such. On the other hand, as stated on page 95:

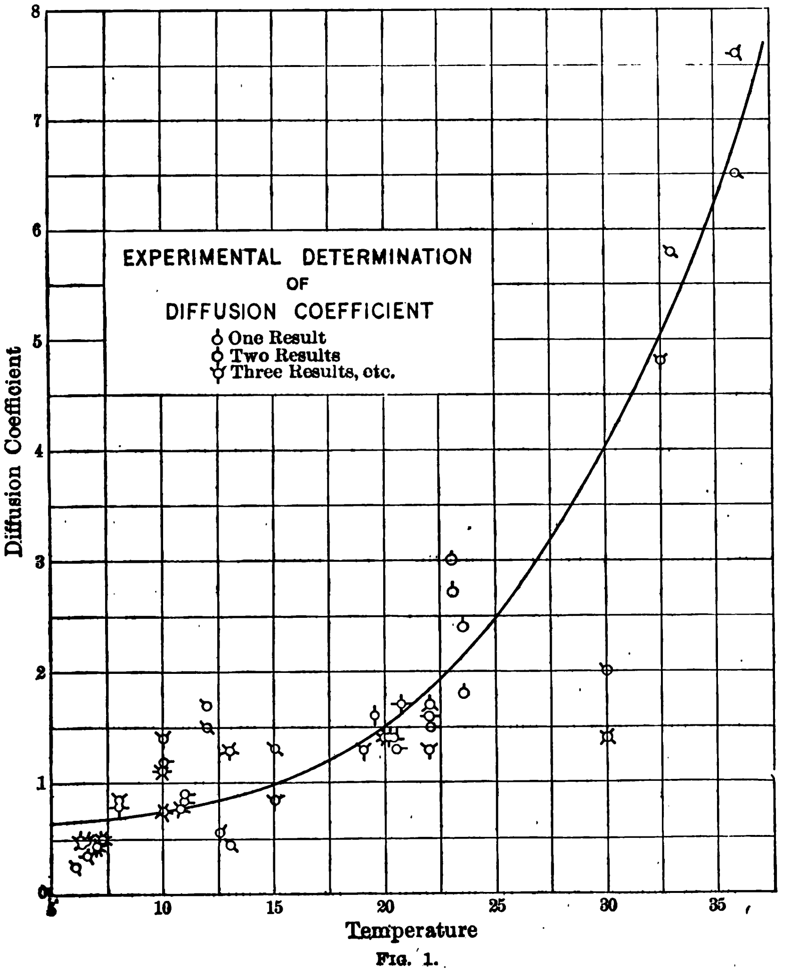

Fig. 1.

"Within the range of values which have been employed in the computations in the text, errors resulting from the maximum divergence of individual tests from the average value of the curve are less than 5 per cent. at the five-foot depths and less than 2 per cent. at the twenty-foot depths."

Surely this is sufficient accuracy for an engineering discussion involving so many unknown factors, as does the New York Harbor problem. The increasing value of the coefficient with increasing temperature, the second point objected to by Dr. Adeney, was not made use of in our discussions. It may be noted, however, that this change is thoroughly concordant, both in direction and in amount, with diffusion coefficients which have been determined for various soluble salts in water. With higher temperature, the molecular velocity of a dissolved substance (that is its tendency to diffuse) increases, and the viscosity of the solution (the resistance to diffusion) decreases.

Dr. Adeney gives (page 85) the results of an experiment from which he concludes: "* * * whether evaporation can or cannot occur, Black and Phelps' proposed formula yields seriously misleading results." The details of the experiment as published are not sufficient to enable one to check our formula by definite computations The experiment is apparently made with "air", and the results are referred to as "Degree of Aeration." The portions of the experimental tube that were examined are defined as the upper, middle, and bottom layers, without any definition of the extent or position of these layers. It is impossible, therefore, to prove or disprove the statement quoted above. Comparison of these experiments with Experiments 8 and 9, reported on pages 62 and 63 of Dr. Adeney's original Report to the Royal Sewerage Commission shows the two sets of experiments to be identical in all their essential features, and, in all probability, the New York experiments numbered 3 and 4 are merely recomputed from the original work. If this supposition is correct, Dr. Adeney has made seven errors in attempting to determine the accuracy of our formula by comparison with these results:

(1) The formula is misinterpreted in that it is assumed to give the increased oxygen content at any depth, whereas its derivation and our use of it show that it gives the total oxygen absorbed by a column of stated depth. This is plainly stated on page 91 of our report.

(2) Our 20° coefficient is used, although the temperature of the

experiments is about 8.5 degrees. Our coefficient for that temperature is just half the coefficient at 20 degrees.

(3) The "re-aeration" was measured by nitrogen, while our coefficient refers to oxygen. There is no evidence that the two gases behave similarly.

(4) The experiments are in sea water, whereas our coefficient refers to fresh water, and we state explicitly that the sea water coefficient is necessarily lower, owing to the increased viscosity of sea water. This effect would be exaggerated at low temperatures.

(5) The computed value was based upon the supposition that the water was free from oxygen at the start, whereas it contained more than 16% in each experiment. Proper use of our formula takes account of the original oxygen content, a self-evident matter which Dr. Adeney consistently overlooks.

(6) In recomputing his results to the basis of "per cent. saturation," the temperature of the room, 10° to 13.5°, is used, instead of the temperature of the water jacket, 8.5 degrees.

(7) In these recomputations, values of zero are arrived at in the middle and bottom layers, whereas in each case in the original experiments a definite amount of re-aeration was noted. The quantities are small, but too large to be ignored when the argument is based upon zero values.

If the writer is in error in assuming that these two sets of results refer to the same experiments, it is merely necessary to point out that they are obtained under identical conditions, so far as the conditions are stated, and, in any event, the writer will deal with the original work, which is fully described, rather than with the apparently recomputed values of the New York Report. The figures of the original report, of the New York Report, and of the former recomputed to the form of the latter, are given in Tables 1 and 2.

The columns referred to in Tables 1 and 2 are the long glass tubes. Air was bubbled through the top layers of three of these in series. The results of the first columns are not given, for the circulating currents established vitiated the diffusion effect.

The experiments are not capable of giving an accurate measure of the diffusion coefficient because of the large percentage errors that are possible and evident in the lower depths of all the columns. Neither are they planned to take advantage of our formula, which gives the

TABLE 1.—Dr. Adeney's Experiments with Sea Water.

Original Experiments. Royal Sewerage Commission Report, Pages 62–63.

Amount of nitrogen in cubic centimeters per liter.

No.	Time, in hours.	Temperature, Centigrade.		1 to 200 mm.		800 to 1 000 mm.		1 600 to 1 800 mm.	
				Columns:		Columns:		Columns:	
		Room.	Jacket.	2	3	2	3	2	3
8.....	Start.	12.8° to 10.0°	8.6° to 8.3°	2.13	2.51	2.13	2.51	2.13	2.51
	48			11.15	11.09	2.29	2.55	2.18	2.51
9.....	Start.	13.7° to 13.5°	8.4° to 8.5°	1.63	1.51	1.63	1.51	1.63	1.51
	48			7.15	6.98	1.65	1.56	1.65	1.52

TABLE 2.—Degree of Aeration, as Percentage of Saturation.

No.	Time, in hours.	Temperature, centigrade.	Uppermost Layer.		Middle Layer.		Bottommost Layer.	
			Columns:		Columns:		Columns:	
			2	3	2	3	2	3
Computations in New York Report, Page 85.								
3.....	48	10.0	72	69	0	0	0	0
4.....	48	13.5	47	47	0	0	0	0
Computations by the Writer for Nitrogen at 8.5 Degrees.								
8.....	Increase in N in 48 hours (in cubic centimeters)		9.02	8.58	0.10	0.04	0.05	0.03
	" " " (percentage of saturation)........		70	67	1.24	0.31	0.39	0.23
9.....	Increase in N in 48 hours (in cubic centimeters)		5.52	5.42	0.02	0.05	0.02	0.01
	" " " (percentage of saturation)........		43	42	0.16	0.39	0.16	0.08

total oxygen absorbed in the entire column. In the course of establishing the formula, we derived an expression for the change in oxygen concentration at any depth. This is shown on page 92, just before the integration. While we have no determination of the coefficient for nitrogen in sea water, it may not be without interest to note that by this formula, under the stated conditions of depth, temperature, and initial content of the water, the increase in oxygen in a column of fresh water at the bottom layer, depth, 1 700 mm., would amount to but 0.1% of saturation, instead of 6%, which Dr. Adeney computes. In Experiment 9, in which the temperature was maintained constant within 0.1°, the results were 0.16% and 0.08% in the two tables. In the other experiment the temperature varied 0.3°, and the results were 0.39% and 0.23%, respectively. Undoubtedly, all results are high, owing to changing temperature and circulation in the tubes. It is evident, however, that the diffusion coefficient of nitrogen in sea water is somewhat lower than that of oxygen in fresh water, and that the mathematical analysis of this problem by Col. Black and the writer, if not supported, is at least not invalidated, by Dr. Adeney's figures.

Discussions of theory and of laboratory investigations on such a complex problem as this are likely to be futile, unless the results can be controlled and checked against actual conditions. The problem of re-aeration is an enormously complicated one, but, fortunately, New York Harbor provides a full-scale experiment, and the various investigations which have been made on its waters have furnished a considerable mass of analytical and other data. It will be of interest, therefore, to inquire to what extent Dr. Adeney's values for re-aeration in a harbor water as a whole differ from those of Col. Black and the writer, and if there be serious difference, how the two sets of values compare with existing conditions. Dr. Adeney states* that any pollution which would not cause a greater rate of absorption than 0.055 c.c. of oxygen per liter per hour would exercise no apparent effect on the aeration of a tidal water. The context shows that he means the condition of aeration, not the rate of re-aeration. Col. Black and the writer have already discussed the errors of this point of view, which gives no consideration whatever to the initial conditions of aeration or of depth. It must be obvious that a saturated water will absorb no oxygen; that there must be a reduction from the normal condition of aeration before absorption begins; and that, furthermore, the greater this reduction the greater the absorption. The figure quoted refers to a mixture of salt and fresh waters in equal proportions, and the value for a mixture containing 75% of sea water is 25% greater. This is the statement taken literally and without question by Edlow W. Harrison, M. Am. Soc. C. E., upon which he based his computation cited by Col. Black and the writer (page 49) to show that the waters of New York Harbor could provide for the sewage of 60 000 000 people without reducing the normal oxygen. Dr. Adeney, in his New York report, makes no attempt to treat the question quantitatively, but points out the serious variation in important factors, and believes that the rate of re-aeration may vary from zero to such a magnitude as to be of practical importance. His only approach to a quantitative statement is to the effect that rates of 0.067 to 0.077 c.c. of oxygen per liter per hour are probably maxima. The average of these two values is equivalent to 0.86 lb. per million gallons per hour, a figure which will be used later for comparison. This value refers to 6-ft. depths, and Dr. Adeney concludes that in greater depths the rate will vary inversely, so that in 12-ft. depths we may assign 0.43 lb. as Dr. Adeney's maximum. In Dr. Adeney's original report, 6-ft. columns were taken to represent actual conditions in practice. Recognition of the depth factor is apparently due to the Black and Phelps formula. Col. Black and the writer also realized the complex nature of the problem, but undertook a definite solution which would involve the most important variables. They estimated average rates of absorption, in 12-ft. depths, of about 0.045 lb. per million gallons per hour, although this figure varies considerably in the various portions of the bay.

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* British Royal Commission on Sewage Disposal, Fifth Report, Appendix VI, p. 67.

Comparison of these figures with Dr. Adeney's maximum, after modification for depth, shows them to be about one-tenth as great. Dr. Adeney confesses his inability to determine an average rate, but claims that it is "of such magnitude as to be of great practical importance." Our figures are average rates, and represent an immaterial quantity in the treatment of the whole subject. While Mr. Harrison's estimate would probably be an unfair statement of Dr. Adeney's views, as now modified in his New York report, it should be noted that it is the only computation that has ever been made to show the value of the "streaming effect," and Dr. Adeney has made no attempt to correct it, or to replace it with a more conservative computation. The Black and Phelps formula has been applied to the conditions existing in New York Harbor, and, in conjunction with Col. Black's excellent mathematical analyses of the tidal conditions existing, has been used as a basis for a computation of the actual condition of the waters of various parts of the harbor. Instead of providing for 60 000 000 people without reduction of the normal oxygen of the waters, we find the effect of re-aeration to be practically negligible. If there be no reduction from the normal there will be no re-aeration. If 30% of the normal oxygen of the harbor waters be used up in sewage oxidation, so that the waters stand at 70% of saturation, the additional aeration will amount to less than 1% of saturation in 12 hours. Under these conditions, oxygen obtained from the atmosphere by absorption would care for the sewage of about 250 000 people, out of a total of 7.4 millions which are provided for by the 30 per cent. The fact that, with less than this population contributing sewage to-day, the waters of the harbor do not stand at their normal oxygen content, but are on the average already reduced to approximately 70% of saturation, is of interest. The calculated condition, assuming practically no reaeration, agrees closely with the facts. A more severe test of our conclusions, however, is possible. The Metropolitan Sewerage Commission made 1 870 analyses for dissolved oxygen in and near New York Harbor during 1911. This work was confined mainly to typical cross-sections. Table 3 shows the original computations by Col. Black and the writer, in comparison with a summary of the Metropolitan Commission's results.

TABLE 3.—DISSOLVED OXYGEN IN NEW YORK HARBOR WATERS.

A. Calculated by Black and Phelps, February, 1911.

B. Analyses by Metropolitan Sewerage Commission for the Year 1911, Reported August 1st, 1912.

Location.	Percentage of saturation.	
	A	*B*
Lower Bay.		
End of flood	100	100
End of ebb	71	74
Upper Bay.		
End of flood	76	79
End of ebb	54	55-56
Hudson to 96th Street.		
End of flood	54	56
End of ebb	48	54
East River.		
Mouth to Hell Gate.		
End of flood	58	55
End of ebb	71	57
Hell Gate to Throgs Neck.		
End of flood	71	57
End of ebb	81	86

The computations refer to the areas indicated in Table 3, while the Commission's figures are necessarily for cross-sections. In each case the value for the area in question at the end of the flood is compared with the average figures for flood and ebb at the cross-section down stream from the area in question; and at the end of the ebb with similar values for the cross-sections up stream from the area in question. In the single case of the Hudson River at 96th Street, at the end of the ebb there are no up-stream data available. The figure given is the average value for the ebb flow at the mouth of the Hudson. Obviously, the character of the water remaining in this section at the end of the ebb is worse than the average ebb flow, a fact which is indicated in the discrepancy of these two figures. With a single exception, the remaining figures show a striking agreement. There is evidently something wrong with our value at the region of Hell Gate, which has influenced the computed value of the ebb-waters below Hell Gate and the flood-waters above. It might be suggested that there is an influence of the Harlem River shown here, which was not properly taken into account in our computation.

The agreement between the computed and the actual conditions, although gratifying, is of itself of little practical moment. Its value lies in the fact that it demonstrates the substantial accuracy of the methods which have been used in the analysis of this problem, and makes it possible to use this same method in computing the probable effect of further increase in population, or of the discharge of additional quantities of sewage from regions not now tributary to New York Harbor. All the facts seem to support the view that aeration in New York Harbor is an immaterial factor in the whole problem of sewage disposal.

Upon the grounds of theory, experiment, and experience, therefore, the writer, much to his personal regret, finds himself obliged to differ from Dr. Adeney, whose personal acquaintance he has the honor to enjoy and for whose scientific work he has the most cordial regard.

DISCUSSION

Dr. Adeney.

W. E. ADENEY, ESQ. (by letter).—In this paper Professor Phelps does not offer any additional experimental evidence in support of the formula which Col. Black and he, in their Joint Report of 1911 to the Board of Estimate and Apportionment, have proposed for calculating the rate at which de-aerated waters become re-aerated, when exposed to natural conditions, in terms of time, depth, initial dissolved oxygen content, and the diffusion coefficient of dissolved oxygen in water.

The fundamental conception underlying this formula is that the re-aeration of de-aerated waters is effected by the absorption of oxygen by the layer of water exposed to the air; that the subsequent transmission of the dissolved oxygen throughout the underlying masses of water takes place strictly in accordance with Fick's law of diffusion; and that, as far as appreciable effects are concerned, no other natural agency or factor need be considered.

The only experimental evidence, which the authors have advanced in arriving at their proposed formula, are some figures, which they have put forward as indicating the diffusion coefficients of dissolved oxygen in distilled water at certain stated temperatures. These figures have been determined by a method which the authors of the formula designed especially for the purpose, but the working details of which have only been slightly indicated in the report referred to.

The experimental difficulties in the way of determining accurately the coefficients of dissolved gases in water are very great, and Hüfner, so far as the writer knows, is the only observer, among the few who have ventured into this field of investigation, who has endeavored successfully to overcome the most serious of these difficulties.

The writer has already pointed out, in Section II of the Report which he had the honor of presenting to the Metropolitan Sewerage Commission of New York in 1911, that the method in question does not determine the diffusion coefficient, but the rate of re-aeration of the water experimented with by quite a different factor, that is to say, by the downward "streaming" of dissolved oxygen from the exposed surface of the water; and, inasmuch as the water used by Col. Black and Professor Phelps in their experiments was not distilled, but contained decided quantities of mineral matters in solution, this "streaming" process must have been very rapid, with the result that the values which they obtained for the diffusion coefficients in distilled water were very much too high.

A rough estimate of the relative rates at which columns of de-aerated sea water may become re-aerated, by (*a*) downward "streaming" from the surface exposed to the air, and (*b*) by true diffusion

Dr. Adeney. in accordance with Fick's law, may be obtained from the results of an experiment which the writer has described, as follows:*

> "A U-shaped tube, each limb 1 600 mm. long and 50 mm. diameter, was filled with boiling sea water and immediately closed air-tight with indiarubber corks. When the water had cooled, the tube was further exhausted by means of a mercury pump. One limb was then uncorked, and the water in it saturated with atmospheric gases by a current of air drawn through the surface-layer to a depth of 50 mm. for 48 hours. After this, a sample was drawn from the bottom of the open limb, and one from the lower portion of the closed limb, about 200 mm. from the bottom. The gases were extracted from these and the nitrogen in each determined, with the following results [expressed in cc. at 0° C., and 760 mm. bar., per liter]:
>
> | Open Limb. | Closed Limb. |
> |---|---|
> | 12.12 | 1.49 |
>
> Six months later another sample was collected from the lower portion of the closed limb, as before, and the nitrogen in it determined; it was 1.73."

These results show clearly that, though the re-aeration of a column of de-aerated sea water, 1 600 mm. deep, and of uniform density, is relatively rapid, so that it may be completely saturated with air in 48 hours when evaporation freely occurs from the surface, it is so extremely slow when dependent on simple diffusion, that it may be altogether neglected in considering questions of the re-aeration of sewage-polluted tidal waters. It may be noted that the temperature of the laboratory during the first two days of the experiment described varied between 10° and 12° cent.

Professor Phelps himself has admitted that his method is faulty. On page 1629 he states in reply to the writer's criticisms:

> "There are admittedly imperfections in the process, and the results are not of extreme scientific accuracy. For this reason, the work, which was originally carried out as a contribution to pure science, was not published as such."

By way of self-defense, he continues to remark that the accuracy of the method is sufficient "for an engineering discussion involving so many unknown factors, as does the New York Harbor problem."

Surely, the problem of determining accurately the diffusion coefficients of dissolved oxygen in water cannot be placed under the category of "involving so many unknown factors." The conditions necessary for the accurate determination of the diffusion coefficients in question are certainly quite well understood, although it may not be easy experimentally to ensure them; and, inasmuch as the whole superstructure of the formula depends on the accurate determination of these diffusion coefficients, the writer ventures to express the opinion that Professor Phelps would have been well advised had he submitted

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* Section I in Appendix VI to the British Royal Commission's Fifth Report, p. 60.

Dr. Adeney.

a detailed description of his method to the consideration, in the ordinary way, of his brother chemists, before applying it to the solution of a problem of such wide and far-reaching importance as that of New York Harbor, affecting, as it does, the well-being of many millions of people, as well as the interests of a vast and rapidly growing commercial center. Had he done so, he no doubt would have had the benefit of the criticisms of other workers, and would not have been left long in doubt as to the nature of the "unknown factor" which has vitiated his coefficient determinations. The writer ventures to think that he has given the true explanation of this unknown factor, in his criticisms* of the method, in which he has shown that the experimental basis of that method is quite erroneous.

Professor Phelps complains (page 1634) that the writer has not suggested a general expression applicable to the calculation of the average rate of re-aeration of tidal waters by "streaming." This was not done, because, to have attempted anything in the way of a working formula for the purpose, he would have had to follow the very undesirable course of making broad assumptions, for which there exists at present no scientific basis. In fact, he would have had to follow the course which he complains that Col. Black and Professor Phelps have adopted in arriving at their proposed formula. The writer is quite willing to admit that such a course would be warranted for the purpose of raising a discussion on the question, if restricted to purely scientific interest, but certainly not in connection with one of such vast practical importance as that of the powers possessed by the tidal waters of New York Harbor for the disposal of sewage matters, within limits of safety to public health, and to the amenities of their surroundings.

The writer has preferred to follow the usual custom by publishing a description of his experiments on "streaming," although they were simply pioneering experiments, and has to acknowledge that he has received the benefit of some helpful criticism from Professor Phelps. He gladly takes this opportunity of expressing his appreciation and thanks for that criticism. The writer has also to express his indebtedness to Professor Phelps for pointing out that the results of his experiments do not bear the precise and general value that has been placed on them by some writers in the United States, because, as already stated, they are only of a pioneering character, and are necessarily only true for the conditions of the particular experiments described.

The fact, however, that the proposed formula rests on an erroneous experimental basis, is not the only serious objection that may be urged against the position that has been taken by Col. Black and Professor Phelps on this question of re-aeration.

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*Report to the Metropolitan Sewerage Commission of New York, 1911, p. 88.

Dr. Adeney.

With reference to the particular question of the re-aeration of tidal waters, Professor Phelps assumes that the same factors obtain with sea water as with fresh water, and that it is effected solely by diffusion, according to Fick's law, from the exposed surface downward.

According to Professor Phelps' strongly expressed opinion, however, the surface layers of inshore tidal waters are fresher by reason of admixture with land waters, and, therefore, less dense than the heavier salt water below. In other words, the layers of water concerned in actually dissolving oxygen from the air, for subsequent diffusion below, are less dense than the lower layer of the water. Notwithstanding this, Professor Phelps assumes that diffusion will proceed according to Fick's law, just as it would were the water of uniform density throughout its depth. Again, he gives no experimental data in proof of this, and the writer knows of none himself. In the absence of direct evidence to prove it, Professor Phelps is not justified, in the writer's opinion, in stating that, because Fick's law holds good for the diffusion of dissolved oxygen in a liquid of uniform density, it must necessarily do so in one increasing in density in the direction of diffusion. Under these circumstances, the writer is entitled to hold the contrary view.

One further assumption, which Col. Black and Professor Phelps make, demands notice. It is stated on page 56 of their original report, and is as follows:

> "Since the fundamental law of aeration is one of diffusion, and, furthermore, since the surface of any body of water is practically saturated at all times, it must be evident that no mere surface action can by itself affect the rate of diffusion."

No experimental evidence of any kind is given in support of this statement. The question is one on which the writer has made a considerable number of experimental observations since he published the description of his pioneering experiments on "streaming," all of which prove beyond doubt that the surface of a body of water, when exposed to atmospheric conditions, does not become saturated at any time as long as the layers immediately below it remain only partly aerated.

The writer has definitely found, by careful experimental observations, that, as oxygen is dissolved by the surface of any quiescent body of water, when de-aerated or only partly aerated, it passes practically as quickly downward through the lower layers, so that the surface does not become saturated until the dissolved oxygen content of the layers below it approach the condition of saturation.

He has found this to be true both of fresh water and of sea water. The only marked difference between the two is that in the sea water the transmission downward is quicker than in fresh water, when the surfaces of the two bodies of water are exposed to the air so that evapo-

Dr. Adeney.

ration can take place freely from them; and *vice versa* when the conditions are such as to prevent evaporation from the exposed surfaces.

The writer has also found that when the surfaces of de-aerated columns of fresh water are exposed to the air, so that evaporation can take place freely from them, and when the columns themselves are maintained at a constant and uniform temperature, the downward distribution of the dissolved oxygen is so nearly uniform, for depths of about 1 000 mm., that the oxygen content of the water at that depth has been found to be nearly equal to that of the surface layer at various stages during the process of re-aeration.

Professor Phelps admits the correctness of the writer's observations on "streaming" in his experiments with columns of sea water, but assumes that "streaming" does not affect the practical question of the re-aeration of tidal waters, because it was caused, as he explains, in the case of the writer's experiments, by the formation of concentrated layers of water, the result of evaporation from the exposed surfaces of the experimental columns; and he assumes that the "streaming" would not occur in tidal waters, when the surface layers are fresher and, consequently, denser than the lower layers of sea water.

Again, Professor Phelps gives no experimental evidence in support of this assumption, and, in the absence of definite evidence, he is no more entitled to make it, than he is to assume that diffusion will occur according to Fick's law under the same conditions.

The writer has already pointed out that if a marked stratification obtains in a tidal water, and the land water lies on the surface of the sea water, the sewage matters, which are themselves carried by fresh water, will gather to the surface layer also and will there be re-aerated chiefly by "streaming."

The New York Harbor waters, however, are not thus stratified. The Metropolitan Commission states:*

> "The general configuration of the bottom and of the main channels of the harbor is such as materially to aid in keeping the water well mixed. * * * The water is usually more saline at the bottom than at the top, but the difference is usually slight and there is apparently no sharp line of demarcation."

Professor Phelps would be justified, no doubt, in assuming that "streaming" would not extend to the lower layers of a tidal water, the surface layer of which consisted practically of wholly fresh water, and the lower layers of undiluted sea water, but he is certainly not justified in assuming, without experimental observation, that it would also not occur in tidal waters in which, as in New York Harbor, the water at a depth of 20 ft. contained, on an average, only 6% more sea water than at the surface. The experiments which the writer has made certainly do not justify such an assumption.

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*1912 Report, pp. 26 and 27.

Dr. Adeney. The writer does not think that any useful object can be attained by following Professor Phelps in his detailed discussion as regards so-called calculated and observed results, because, until the scientific basis on which such a discussion can be usefully carried on has been definitely settled, it can only be juggling with figures to attempt to do so.

In his Report to the Commission (page 81), the writer has mentioned the chief factors, as far as they are known, which are concerned in the re-aeration of tidal waters exposed to natural conditions, and gives reasons for believing that:

"The rate of re-aeration must therefore be an extremely variable quantity from day to day, and even from hour to hour."

Again, on page 87, he states:

> "It is quite evident that under their combined influence [*i. e.*, the factors concerned in re-aeration] the rate [of re-aeration] may vary practically from zero to a value of such magnitude as to be of great practical importance especially during summer season.
>
> "It need scarcely be pointed out, however, that a good deal of work has yet to be carried out, both in the laboratory and on the open water, before a definite value can be put to the extreme rate at which re-aeration under the most favorable conditions would occur, or even to the average rate—both would certainly vary with different classes of inshore waters."

Mr. Phelps. EARLE B. PHELPS, ASSOC. AM. SOC. C. E. (by letter).—The writer wishes to thank Dr. Adeney for his frank criticism, which makes it possible to define clearly the points at issue. There is apparently complete agreement on the two propositions that diffusion alone is of no material advantage in the re-aeration of polluted tidal waters and that the phenomenon of "streaming," if it takes place, effects re-aeration to a material extent. This being the case, further discussion of the accuracy of the determination of the diffusion coefficient becomes irrelevant. The writer sees no reason to alter his opinion that figures of this degree of accuracy, although admittedly too imperfect for use in a journal of physical chemistry, still have a legitimate use, especially when the probable magnitude of the error is stated. A review of the original data, in the light of the criticism made, leaves the writer still of the opinion that Fick's law holds in this case, that the mathematical analysis of the problem is sound, and that the value of the coefficient as determined has a degree of accuracy better than that obtaining in other important engineering values that enter the problem, such as the measurement of stream flow and of sewage.

There remains, however, as relevant to this discussion, the single question: "Does streaming take place in New York Harbor?" Dr. Adeney apparently accepts the writer's explanation of the nature of the streaming phenomenon, so far as saline waters are concerned, in

Mr. Phelps.

that it is a gravitational movement of the more dense layers produced at the surface by evaporation. He objects, however, to the "assumption" that this process is not taking place in a body of water in which the density actually increases from the surface downward. Surely this is more than an assumption, and it calls for no experimental proof that lighter layers of water will not sink through heavier layers by the action of gravity. The quotation from the Metropolitan Sewerage Commission's report is not a sufficient basis for the statement that the waters are not stratified, if by stratified we understand an increase of density downward. The figures and diagrams of that report show such a condition almost universally, and the writer's experience, in the Charles River Basin at Boston, and elsewhere, indicates such a condition to be normal in estuary waters. Whether the density gradient be great or small, and whether or not there be a distinct line of demarcation (which is often found), the mere existence of a density gradient downward is obviously incompatible with a downward gravitational streaming of water.

Dr. Adeney does an unintentional injustice to our formula when he states at the outset that it determines the rate of aeration in terms of time, depth, initial dissolved oxygen content, and diffusion coefficient; and (later) that "no other natural agency or factor need be considered." A study of the method of using the formula will show that the time factor is the mean time between uniform mixings, and that for its determination one must know all the physical conditions and natural agencies that assist in mixing the water, such as wind, tidal mixing, and the effect of passing boats. This work is now being extended by the determination of the time factor for streams of various types. Knowledge of this factor will make it possible to determine the rate of re-aeration of such streams. The formula has already been made use of in this way by the experts of the Royal Sewerage Commission of Great Britain, in its Eighth Report. The results show at once that the possibilities of re-aeration in such streams are far greater than in the case of deep estuaries.

The writer cannot agree that the correspondence between calculated and observed results in New York Harbor is only a "juggling with figures." The calculated results are based on the practical negligibility of re-aeration. The fact that they agree to a remarkable degree with the results of an extensive series of analyses made during the following year is certainly the most desirable kind of "additional experimental evidence," the absence of which Dr. Adeney regrets so keenly. If these calculations had been made by omitting all reference to re-aeration, the results would not have been altered materially. They do not involve any of the disputed points, and, without further reference to the other matters, they alone show the practical non-importance of re-aeration in New York Harbor.

THE CHEMICAL MEASURE OF STREAM POLLUTION AND SPECIFICATIONS FOR SEWAGE EFFLUENTS

EARL B. PHELPS

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THE CHEMICAL MEASURE OF STREAM POLLUTION AND SPECIFICATIONS FOR SEWAGE EFFLUENTS

EARLE B. PHELPS.

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Chemical analysis has long played an important part in the determination of the degree of pollution of natural waters, and in the measurement of the results of sewage purification. The methods employed for this purpose have been inherited from the older methods of water analysis almost without change. The latter were designed primarily to determine the purity of drinking waters but they have been adhered to in sewage work despite the fact that sanitarians have long since abandoned the idea of maintaining streams at a drinking water standard and in disregard of the present day aspects of sewage disposal. Sewage purification is essentially oxidation of organic matter. In the wellnigh perfect work of the slow sand filter the oxidation was so complete that it was conveniently measured in terms of nitrification. This is not a true quantitative measure of the whole work of the filter, but appears to be an end-point reaction indicating the completion of the process. With the introduction of rapid methods of purification designed for partial oxidation only, the test of nitrification and the whole scheme of chemical analysis fail utterly to meet the requirements of the situation. Hence the recent development and general use of putrescibility determinations. From a stream pollution aspect the older analytical procedure not only fails to define the quality of an effluent, but is actually misleading. Lederer[1] has shown that the removal by sedimentation of 63 per cent. of suspended solids results in an improvement in stability of only 31 per cent. In dealing with oxidation processes and employing as criteria of improvement the decrease of albuminoid ammonia and of oxygen consumed, the opposite effect is noted. A complete removal of the putrescibility of the sewage may be accompanied by an improvement in these analytical values of not over 50 per cent.

In stream pollution studies the condition is, if possible, a more serious one. Here there is no "per cent. removal" with which to cover the uncertainty of the result. We are given a definite statement that the stream in question contains so many parts per million of free and albuminoid ammonia or of organic nitrogen or oxygen consumed. We are expected from his information to draw a conclusion as to the present condition of the stream in question and the possible effect upon it of the discharge of additional sewage either untreated or partially purified. If these analytical determinations do not enable one to distinguish between organic matter in its crude state and this same matter after passage through an oxidizing filter, he would be a wise chemist indeed who could give any proper interpretation to the results of such a stream analysis.

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[1] Am. Jour. Pub. Health, Vol. 2, 1912, p. 97.

In approaching this problem, it is first necessary, as in the case of any measurement, to establish a scale or basis for such measurement. We are not dealing, in stream pollution, with albuminoid ammonia, or oxygen consumed as measured by boiling permanganate. We are dealing with nuisances of one kind or another. Let these be briefly enumerated.

There may be a bacterial nuisance, or danger, if water supplies or shell fish are involved. If so, our basis of measurement must also be bacterial, and not only that, but it must either be directly based upon the kind of bacteria which we desire to avoid, or if indirect, must bear some such definite relation to the undesirable germs that there can be no possible confusion. Even in such a simple matter as this, results of a misleading character are often reported. The total bacterial content of an unpolluted up-land stream, or of a sewage, stored after thorough disinfection, may vary enormously, but such variations have no sanitary significance.

If the removal of dangerous bacteria be one of the purposes of the purification treatment, then and only then is there a logical place for bacterial tests in the scheme of analysis adopted. The technique employed and the interpretation of the results must both bear recognition of an important fact; namely, while the removal of pathogens may safely be assumed to be no less complete then the corresponding reduction of total bacteria, the latter are subject to a subsequent rapid multiplication, not possible with the pathogens. This is especially important in the case of chemical disinfection. The time and place of sampling must be selected to obtain the maximum effect of the disinfectant and the minimum effect of the subsequent increase in normal bacteria.

Again the nuisance may be of purely physical character, due to the deposit of suspended or precipitated matter. Here also the basis of measurement must conform. Quantitative studies of suspended matter have, therefore, a direct bearing, but the ordinary "suspended solids," determined by filtration through paper, is of little interest. The English and German methods of determining "solids capable of settling" give results of more immediate value, for they show at least the present character of the sewage. Methods are still lacking for determining the rate of change in respect to suspended matter. Oxidation changes tend to precipitate soluble and colloidal substances, and sea water has a similar effect. Future research must attack this problem and must also recognize the time element in sedimentation. Strictly it is the "rate of sedimentation," not the total amount of sediment, that must be considered in computations of possible nuisance. Solids capable of settling may be lower in total amount in a trickling filter effluent than in the corresponding sewage but their rate of settling is very much greater. In a stream they would deposit sooner, or would require a greater current velocity to prevent deposit.

The most common and most undesirable type of nuisance is that which may occur in polluted waters because of the exhaustion of the natural purifying powers. We deal here not with mere pollution, which is intentional, but with the determination of the capacity of the body of water to receive and dispose of sewage without the production of unsightly appearances or unpleasant odors. The latter are determined by certain bio-chemical reactions, which in their turn are most definitely related to the supply of available oxygen. These bio-chemical reactions can, therefore, be definitely measured and they constitute a true measure of the nuisance. Moreover, a proper knowledge of this relationship and proper tests of the sewage or of the effluent make it possible to determine in advance the final result of any anticipated pollution.

The actual scale to be used in making this measurement is, therefore, one of oxygen values. The zero point of the nuisance scale may be taken at the oxygen condition of normal unpolluted waters of the particular type in question. The 100 per cent. point of this scale may be defined for the present as the point at which an obvious nuisance exists in the stream. This latter point is indefinite in so far as there is at present no general concensus of opinion concerning it. The available evidence indicates that in slow-moving bodies of water a definite nuisance will result from the lowering of the dissolved oxygen below 50 per cent. of saturation in the summer time. A more definite statement of this matter is not necessary for the present discussion. In each individual case there must be a definite point at which nuisance begins and, wherever it be, this point represents the maximum permissible pollution and is the upper limit of the nuisance scale.

It would seem, therefore, to be a simple matter to define any intermediate stream conditions with reference to these two fixed points, but the matter is not quite so free from complications. The reactions involved are bio-chemical in their nature. The problem deals with progressive changes not with fixed conditions at any one moment. It requires for solution the establishment of a fixed point and of the direction and velocity of existing changes. The direction of the change may be toward either end of the scale according as the putrefying tendencies or the natural oxidizing agents of the stream are predominant. The former are now capable of exact determination as will be shown. The latter depend upon the physical characteristics of the body of water in question, and primarily upon the possibilities of re-aeration. In a quiescent body of water re-aeration is almost negligible and improvement by this means is at a minimum. In shallow, swiftly flowing streams the maximum effect is obtained. The determination of the magnitude of re-aeration in moving bodies of water constitutes one of the most important fields of future research in stream pollution. Until this matter is placed upon a strictly scientific basis, the capacity of such streams to dispose of organic matter can be known only empirically. The absolute effect of the polluting matter upon quiescent water on the other hand is strictly determinable. The methods which Black and the writer have elsewhere proposed[1] are direct and simple in application. It is assumed in the first place that the well-known mass action law of physical chemistry holds for these reactions, an assumption which has been amply justified experimentally. Moreover, the reaction being a biochemical one is monomolecular. According to the mass action law, the velocity of such a reaction at constant temperature is a direct function of the concentration of the reacting substances, in this case the oxidizable

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To correct typographical error in June Journal. Please insert this slip on page 527, line 12:

organic matter and the oxygen. The integrated form of the differential equation expressing this law becomes, log. $\frac{O}{o} = KtC$, in which O is the initial concentration of dissolved oxygen, o the final concentration, t, the time elapsing between the two tests, C, the concentration of the organic matter, and K the velocity constant of the reaction. For convenience the oxygen values are expressed in the unit, parts per million or mg per liter; time, in hours, and concentration of organic matter in per cent. of sewage by volume in the mixture or in the stream.

time be noted in the experiment the equation may be solved for K. Hav ing thus experimentally fixed the velocity constant of the formula for th sewage in question it is possible to determine the future course of th reaction at the given dilution and over any desired period of time. Stil neglecting the re-aeration factor, the result of any anticipated stream pollution can be determined by simple tests of the sewage itself and by a knowledge of the dilution ratio in the stream. Hence the importance of further information on re-aeration in running waters, or of some empirical measures of the capacity of the stream to purify itself before the problem can be completely solved.

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[1] Report of Col. William M. Black and Earle B. Phelps on the Discharge of Sewage into New York Harbor, New York City, Mar. 23, 1911. Contribution from the San. Res. Lab. of the Mass. Inst. Tech. Vol. VII.

It will be noticed that in this discussion no attention has been paid to the actual quantity of organic matter present, which is usually determined. A small quantity of albuminoid ammonia or organic nitrogen in the form of highly putrescible material, such as fresh sewage, will exert the same influence as a large quantity in some stable form, such as is found in a partially purified effluent. It has even been found that artificial aeration of sewage may reduce its oxygen requirements materially without effecting any change whatever in the ordinary chemical analysis. It is not the quantity of organic matter, but its oxygen requirement which determines its effect upon the stream.

These principles may now be still further applied and in a more definite manner to the old problem of standards for sewage effluents, many bases for which have been proposed in the past. The most common of these is the "per cent. purification" referring to certain of the analytical features. A removal of 90 per cent. of the "albuminoid ammonia" or of the "oxygen consumed from permanganate" is given as a measure of the results of purification. If albuminoid ammonia or oxygen consumed had any definite relation to the nuisance scale which has been described, then their removal would be a definite measure of improvement. As they are found to have no such relation, their measurement can only be misleading.

In any case the total amount of polluting material discharged is the determining factor without reference to any previous degree of purification. One million gallons of crude sewage would work the same harm as two million gallons of half purified effluent, or ten million gallons, 90 per cent. purified. Hence, after a proper measure of polluting material has been established, the absolute character of the effluent and its volume, alone constitute the measure of its effects upon the stream. The expression "per cent. removal" is of interest only in experimental and preliminary studies.

Other standards for effluents have from time to time been proposed. They deal for the most part with absolute quantities but are in general faulty in two respects. Except for suspended matter they are based upon determinations that have no direct relation to the nuisance in the stream and they take no cognizance of the relative volume of stream and effluent.

The oxygen requirement of the liquid in question is the logical starting point for any quantitative statement of results. If this fact be admitted, the resulting solution is self-evident. Take, for example, a crude sewage. Let this be diluted in aerated water in a proportion, let us say, of five or ten per cent. Then let the oxygen of the resulting mixture be determined in one sample at the start and in another sample at the expiration of twenty-four hours. The resulting loss is the oxygen requirement of this mass of the sewage during twenty-four hours at the temperature of storage. A definite proportion of the oxygen requirement of the sewage will have been satisfied. According to the mass action law already explained, the same proportion of the remaining oxygen requirement will in the presence of sufficient oxygen be satisfied during the next twenty-four hours and so on a diminishing ratio until equilibrium is reached. Knowing the form of this reaction curve, however, it suffices to consider it experimentally only during the first period. If the conditions are such that within twenty-four hours the stream in question will have entered the ocean or a much larger stream where ample dilution is provided, the oxygen requirement for 24 hours, as determined, need merely be balanced against the oxygen resources of the stream. It may be, however, that within six hours such ample dilution will be provided, or it may be several days. By use of the formula the net requirement, over any stated period of time, is readily determined. Moreover, it may appear that the dilution used experimentally is not that actually available in the stream. Again within reasonable limits the experimental results can be transformed to meet the practical requirements by the substitution of the proper dilution factor C. In the case of an effluent the procedure is exactly the same. If the effluent be sufficiently good no dilution will be necessary. The loss of dissolved oxygen of the stored effluent will be noted and the oxygen requirement of the organic matter over any period of time and in any other dilution will follow.

Under this procedure it is necessary to look first to the stream rather than to the effluent in the establishment of standard requirements. The stream without re-aeration has a definite quantity of available oxygen. It may be decided that this oxygen supply shall not be reduced to less than 50 per cent. of the saturation value during the warm months. If information is available on the rate of re-aeration, this additional oxygen may be added to the available supply in the computation. In the absence of any such information re-aeration may be left as a factor of safety. Starting with a definite oxygen availability in the stream and with known populations contributing pollution to the stream, the stream's power to purify sewage may be divided per rata among those populations, in actual quantity of oxygen expressed in any convenient unit, such as pounds per day. In each community then, the oxygen requirements of the sewage or effluent to be discharged must not exceed the available appropriation for that community. Allotments of this character must be made also for the future and not for the present. A young, rapidly growing community may have the same rights in the natural resources of the stream as its older and larger neighbor. If purification is to be demanded and if each community be restricted to a definite allotment of the available purifying capacity, then the small growing community may at the start require no purification of its sewage, while its larger sister may reasonably be held to a much more severe standard. As it grows the younger community will gradually use up its appropriation and will be forced to partial purification. It should be the function of the central state authority to determine these allotments and to warn the various communities of the probable requirements of the situation in the near future. From time to time the actual oxygen requirements of the wastes of each community should be determined. This is done simply by testing properly collected samples of the sewage and calculating from the results of this test expressed directly in oxygen terms, and from the volume of sewage, the total oxygen requirement of the sewage in question. That community which may be situated nearest to the ocean has a geographical advantage which allows the use of a shorter time factor. In the case of New York Harbor and its tributary waters for example, a period of six hours suffices in many cases for the ample dilution of polluting material. The cities of Albany and Troy, however, discharging sewage ultimately into the same body of water would have their oxygen requirements determined through a period of weeks.

The matter of temperature has heretofore been touched upon but lightly. In bio-chemical reactions, however, this is a fundamental factor. The condition of a sewage measured by its oxygen requirement has been found to change as much as ten fold between early and late spring. In the warm weather also water carries less dissolved oxygen and the biological activities upon which all these results depend are enormously increased. Therefore, in all this work, summer conditions of temperature and stream flow must be considered. It is useless to make calculations under any other conditions. If summer conditions are adhered to the results will be satisfactory throughout the year. In determining the stability of a sewage or an effluent in the laboratory the work should be done at a temperature of approximately 20°. Higher temperatures have been suggested and in routine studies of sewage effluents these may be used with the understanding that they are indirect and must be frequently checked against the 20° result. All final expression of oxygen requirement must be referred to the 20° temperature, which most nearly approximates the summer temperature of streams. Not only is the velocity of the reaction increased at higher temperatures but the character of the active organisms is altered and there is no necessary constant relationship between the results at these two temperatures. Results can be obtained in a much shorter time at 37° and if these be frequently checked against the standard conditions their use is permissible.

In advocating this direct method of treating stream pollution problems, the writer makes no claim to originality, except in that he has brought together methods and ideas from various independent sources. The mathematical treatment of the subject is one familiar to physical chemists. The analytical methods that are advised have long been used.

In 1870, Doctor Edward Frankland published detailed experimental results based upon the analytical determination of oxygen absorption in incubated samples. Frankland states[1] "Whether we examine the organic pollution of a river at different points of its flow, or the rate of disappearance of the organic matter of a sewage when the latter is mixed with fresh water and violently agitated in contact with air, or finally *the rate at which dissolved oxygen disappears in water polluted with 5 per cent. of sewage,* we are led in each case to the inevitable conclusion that the oxidation of the organic matter in sewage proceeds with extreme slowness: . . ." (The italics are mine.)

Frankland also refers to similar work by Sir Benjamin Brodie, published in 1886,[2] Spitta[3] in 1900 published two papers upon the self-purification of streams. He showed that in a polluted water, incubated, the oxygen absorption was dependent upon the availability of the organic matter as a bacterial food. He experimented with asparagin, ammonium-lactate, urea, dextrose, and cane sugar. Spitta makes no claim of originality for the analytical procedure which he uses and which is identical with that proposed here. He refers incidentally to similar work by Gerardin, 1875[4] and by Reichard, 1875. Letts[5] reported similar experimental work without making special comment on the analytical methods employed, which were evidently not new with him, and Adeney,[6] McGowan[7] and various other workers of the Royal Sewerage Commission of Great Britain have used the same methods. The use of oxygen absorption as a measure of the character of organic matter, is a matter of so long standing and of such general common knowledge that citation of original authority is as unnecessary as claim of originality would be futile. Nevertheless, Clark [8] points out that the method which is here proposed for dealing with this general problem and which was first published in the report on New York Harbor, previously referred to, cannot be original since he made oxygen absorption tests in 1900, and that so far as he is aware such tests were original with him. It is perhaps unnecessary to add that this well-known method of investigation is merely a useful tool in the work which is here proposed. The first serious suggestion to utilize oxygen absorption as a criterion of sewage strength and of the work of a filter, so far as the writer is aware, was made by McGowan[7] although Adeney[6] had paved the way for this suggestion by a most elaborate experimental investigation. In this country Hoover[1] has made the first successful attempt to apply these suggestions in practice.

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[1] First Report, River Pollution Commission of 1868, p. 21.

[2] First Report, River Pollution Commission of 1865, Vol. II, p. 49.

[3] Arch. of Hyg. 38, 1900, p. 215.

[4] Compt. Rend. 1875, p. 989.

[5] 5th Report Royal Sewerage Commission, App. VI.

[6] Proc. Royal Dublin Soc. IX, 1900, p. 333.

[7] 5th Report Royal Sewerage Commission, App. IV.

[8] Mun. Journ. XXXI, 1911, p. 429.

The writer had endeavored to broaden the scope of these general principles and extend their applicability to stream pollution problems in general. The view that we are dealing here with a definite set of chemical reactions, and the establishment of the fundamental chemical law by which those reactions proceed, seems to be essential to the full extension of the chemical work, and to a complete treatment of the results. The writer's earlier work on the methylene blue test [2] was based upon the same fundamental conceptions and the general adoption and satisfactory application of the relative stability number thus derived testifies to its soundness and value.

The formulation of the chemical law involved, in its differential form, is for all practical purposes an exact one. Owing to the varying possible relationship between oxidizability on the one hand and oxygen on the other, no general integration is possible. The assumption of a constant oxidizability during the progress of the test is reasonably approximate, and becomes more nearly true with increase of oxidizability, and shortening of the period of incubation. It becomes less accurate, therefore, in the case of well purified effluents, and is most available with sewages. Work is now in progress by which it is hoped to place this matter upon a more accurate basis.

The formula which is here proposed has been used in investigations of the pollution of New York Harbor with gratifying results. Determinations of the oxygen requirements of the sewage of one of the main outfalls of Brooklyn were made during an entire summer season. Upon the basis of these figures, of the contributing population and total flow in the area studied, and of an assumed contributing populations over all areas tributary to New York Bay, the actual withdrawal of oxygen from the various large subdivisions of the Bay was calculated. The resulting figures were further slightly corrected for re-aeration after a careful study of that problem. The results of these computations are shown below, side by side with the actual determinations made the following year by the Metropolitan Sewerage Commission. The Sewerage Commission's figures were obtained by careful study of certain cross-sections during various stages of the tide.

Dissolved Oxygen in New York Harbor Waters.

A. Calculated by Black & Phelps, February, 1911.

B. Analyses by Metropolitan Sewerage Commission for the year 1911, Reported August 1, 1912.

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[1] Eng. News. 65, 1911, p. 311. 68, 1912, p. 451.

[2] U. S. Geological Survey, Water Supply Paper, 229, 1909.

	Per cent. A	Sat. B
Lower Bay:		
End of flood,	100	100
End of ebb,	71	74
Upper Bay:		
End of flood,	76	79
End of ebb,	54	55–56
Hudson to 96th Street:		
End of flood,	54	56
End of ebb,	48	54
East River Mouth to Hell Gate:		
End of flood,	53	55
End of ebb,	71	57
Hell Gate to Throg's Neck:		
End of flood,	71	57
End of ebb,	81	86

Our computations refer to the areas indicated in the table, while the Commission's figures are necessarily for cross-sections. In each case the value for the area in question at the end of the flood is compared with the average figures for flood and ebb at the cross-section down stream from the area in question; and at the end of the ebb with similar values for the cross-sections up stream from the area in question. In the single case of the Hudson River to 96th Street at the end of the ebb there were no up stream data available. The figure given is the average value for the ebb flow at the mouth of the Hudson. Obviously the character of water remaining in this section at the end of the ebb is worse than the average ebb flow, a fact which is indicated in the discrepancy of these two figures. With one single exception, the remaining figures show a striking agreement. There is evidently something wrong with our values at the region of Hell Gate, which has influenced the computed value of the ebb waters below Hell Gate and the flood waters above. It might be suggested that there is an influence of the Harlem River shown here which was not properly taken into account in our computation.

The agreement between the computed and the actual values, although gratifying, is of itself of little practical moment. Its value lies in the fact that it demonstrates the substantial accuracy of the methods which have been used in the analysis of this problem and makes it possible to use this same method in computing the probable effect of further increase in population, or of the discharge of additional quantities of sewage from regions not now tributary to New York Harbor. In this way the writer has computed the effect of the discharge of sewage from the proposed Passaic Valley sewer and the satisfactory results shown above give reasonable assurance that these computations, based upon the same general formula and hypotheses, are substantially accurate.

SUMMARY.

Bacterial tests may be used to measure the results of disinfection treatment, whether it be by biological or chemical means. Determinations of "solids capable of settling," including matter that may be precipitated, and especially the "rate of sedimentation," are needed when sedimentation is a factor in stream pollution.

The quantity of organic matter present in a sewage or effluent or in a polluted stream is in no sense a measure of the effect of that organic matter upon the stream. That effect can best be measured and expressed in terms of oxygen requirements. Since the oxygen reactions are progressive, the statement of oxygen requirement must be made for a definite period of time. This requirement may be determined experimentally in the laboratory by noting the rate of decrease of dissolved oxygen in an incubated sample, diluted if necessary, and by making the proper substitutions in the mass action formula which has been found to apply to this case. The ultimate oxygen requirement of the sewage of a community expressed in pounds per day may then be balanced against the available oxygen resources of the stream into which this sewage is to be discharged, and the resulting figure will show the effect of such discharge upon the dissolved oxygen of the stream. If the effect is to reduce the dissolved oxygen of the stream below the permissible point, further purification is indicated. If two or more communities are contributing to the same body of water the total oxygen of the water may be apportioned in an equitable manner between them. In all these computations, summer conditions of temperature and stream flow must be assumed and in each individual case the time factor of the formula must be made to correspond with the time required for the body of sewage in question to become sufficiently diluted in an increasing volume of water to carry it safely beyond the danger point. The examination of crude sewage is of value in experimental studies of purification methods but the absolute quality of the effluent alone effects the stream, regardless of the relative improvement.

Chemical analysis of a sewage or effluent conveys no information that is at all commensurate with the labor and cost involved. The interests of economy and scientific accuracy demand that the routine analysis be replaced by tests, having direct bearing upon the particular case, and interpreted in the light of full knowledge of the volume and physical and chemical characteristics of the body of water into which the effluent flows.

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BIO-CHEMISTRY OF SEWAGE

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In an earlier paper[1] the writer has dealt with the question of the interpretation of a sewage analysis. Such an interpretation in its fullest sense would involve a complete statement of the physical, chemical and biological properties of a sewage as indicated by the ordinary analytical results. It was shown that the analytical figures usually obtained did not provide sufficient information to permit of any such thorough interpretation. The problem was therefore somewhat simplified by first defining three groups of characteristics of a sewage and attempting to correlate them with the analytical features. These three general properties of a sewage may be briefly defined as follows:—

The physical property of concentration refers simply to what is ordinarily known as the strength of the sewage. The chemical property of composition refers to the type or kind of sewage. For example, the wastes of the various manufacturing industries differ from one another and from domestic sewage in composition. The third characteristic is the bio-chemical one which was called the condition of the sewage. This is in large measure independent of the other two and is determined by such factors as age, temperature, and biological activity.

In the paper referred to, especial attention was given to the first two groups of characteristics, the physical and chemical. It was found that current methods of analytical procedure gave little information concerning the bio-chemical property. Some study of dissolved oxygen in the Boston sewage indicated that there was an interesting relationship between temperature and dissolved oxygen, and it was assumed that this relation was of even deeper significance, and that the dissolved oxygen itself was an indirect measure of the condition of the sewage. With increasing temperature the dissolved oxygen normally present in sewage was found to decrease steadily until it completely disappeared. There was interesting graphical evidence that beyond this point there existed a condition of negative dissolved oxygen or oxygen avidity, a point which has since been experimentally demonstrated. Beyond this there was nothing in the methods of analysis in use at that time to indicate sewage condition. The older sewage chemistry, which was built about the nitrogen cycle, has proven itself utterly inadequate to meet the demands of modern studies in purification and in stream pollution. There has, therefore, in recent years, been a marked tendency toward a more detailed study of oxygen relationships with a corresponding elimination of much of the nitrogen work. This newer sewage chemistry has been developed along the line of putrescibility studies, although its scope has been extended far beyond that originally included under the term "putrescibility of sewage." The results have thrown further light upon the question of the condition of sewage as previously defined and have fully justified the emphasis which was originally given to this almost hypothetical characteristic.

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[1] Tech. Quart. XXVIII, 1905, p. 40.

In stream pollution studies it is the oxygen relations that are relied upon almost wholly. Modern sewage disposal and stream pollution questions have come to be less and less questions of sanitary significance, and more and more matters of physical nuisance; and the question of nuisance in a stream is now recognized to be merely a question of a balance between available oxygen and the oxygen demands of the polluting material. Under these circumstances determinations of free and albuminoid ammonia give no information whatever upon the real condition of the stream, nor could one, however experienced, deduce from an ordinary chemical analysis of sewage the effect of the discharge of a stated volume of such a sewage into a known body of water. In other words, no correlation has yet been discovered between the concentration and composition factors of sewage and its oxygen requirement. The latter is a purely bio-chemical property as is evidenced by the fact that a sterile sewage discharged into a sterile stream would have no oxygen requirement, whatever might be its chemical analysis. The time is therefore opportune for a brief review of our present knowledge of the bio-chemistry of sewage as shown by its oxygen relationships.

The determination of dissolved oxygen in sewage and in effluents has always been an integral part of their chemical analysis. This determination was inherited along with the others from the older water analysis. No attempt at quantitative interpretation, however, was ever made, so far as the writer is aware, and the dissolved oxygen factor was recorded along with the nitrogen and other factors as a part of the general scheme of sewage analysis. It was assumed in general that the higher the dissolved oxygen and oxidized nitrogen the greater the purification. As long as purification was defined as oxidation of the nitrogenous constituents of the sewage and was made synonymous with nitrification, such an interpretation was unobjectionable. From the more modern viewpoint this conception of the rôle of oxygen is erroneous, as will be shown. Aside from the dissolved oxygen determination, no attention was given to the bio-chemical factors until the early efforts of the English chemists to measure putrescibility. A historical summary of these putrescibility studies has appeared in an earlier paper[1] and this matter will not be recapitulated. It is sufficient to point out that in all these early attempts putrescibility was regarded as a definite property, the opposite of stability, and all measures of this property were qualitative. In the earliest form the test involved the storage of a sample of effluent in a tightly sealed bottle for a definite period of time. If it became foul-smelling it was reported as putrescible, if not, as stable. Later this test was placed upon a more definite basis by the discovery, in methylene blue, of a very satisfactory indicator. The use of this dye was first suggested by Spitta and later by Spitta and Weldert. In this country Phelps and Winslow[2] reported an extensive study of the method and urged its adoption in place of the indefinite smell test.

While the introduction of the methylene blue test was a distinct advance in putrescibility studies, the whole matter was still on a qualtitative basis. The question whether an effluent was stable or not depended to a very large extent upon the technique of the test, particularly upon the establishment of a definite time and temperature. Obviously this procedure was fundamentally wrong. If stability be a definite qualitative characteristic it ought not to be possible to find an effluent stable by a four day test, and putrescible by a five day test, yet such a condition actually existed. If on the other hand, stability be looked upon as a quantitative property to be measured and stated in definite numerical terms, then all the analytical results are harmonized. This viewpoint is so fundamental to the present discussion that it will be illustrated more fully.

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[1] Phelps & Winslow, Jour. Inf. Dis., Supp. No. 3, 1907, p. 1.

[2] Loc. cit.

Putrescibility may be defined as the availability of the substance in question as a bacterial food. Stability is the converse of this. Protein material may be taken to represent one end of the scale and leaf mold or humus the other. Between these two extremes one may find organic substances of all degrees of availability as bacterial food. Sewage purification, as we know it today, is a process of so altering the chemical properties of organic material as to increase its stability. This may or may not be accompanied by processes of nitrification. It is essentially oxidation. In its incomplete form it is principally oxidation of carbonaceous material and can be measured only on a stability scale. A high degree of purification may be obtained without any material oxidation of the nitrogen. This oxidation is commonly held to be biological. Upon this matter, however, there is some slight disagreement and very little real evidence. Whether it be primarily biological or primarily physico-chemical, but dependent upon a biological substratum, matters little in practice. One might indeed urge that all life processes are essentially physico-chemical. Bio-chemical changes which take place during purification treatment have as their net result the shifting of the position of the organic matter towards the stable or humus end of the stability scale. Only in extreme cases is perfect stability reached. Therefore, any correct measure of sewage purification must be a quantitative one and a putrescibility or stability test must be devised to give quantitative results.

This problem has been approached from the standpoint of the mass action law of physical chemistry. A definite chemical reaction takes place during the storage of a sample of effluent in a tightly stoppered bottle. This reaction is a bio-chemical one maintained by the micro-organisms present. So far as reactions of this kind have been studied, they have been found to be monomolecular in a physico-chemical sense. As a first approximation it was assumed that this reaction also was of the first order. The final results justified this assumption. There is in this reaction then a gradual reduction of the available oxygen of the effluent and a corresponding reduction of the oxygen requirements of the organic matter present. These two reductions must balance. The velocity of the reaction follows the logarithmic curve of first order reactions. By the use of methylene blue as an indicator, the zero oxygen point is shown. If the oxygen available in the sample in the form of dissolved oxygen and of nitrates and nitrites were exactly equivalent to the maximum oxygen requirement of the organic matter, the reaction would proceed forever at a decreasing rate and the oxygen would never become exhausted. This is a condition which may be termed perfect stability in the effluent as a whole. This conception must be clearly distinguished, however, from stability in the organic matter alone. I have, therefore, called the former relative stability. It may be defined as the relation existing between the oxygen requirements of the organic matter present and the available oxygen existing in the effluent. Knowing the mathematical form of the reaction curve and the time required for the complete reduction of the available oxygen, it is a simple matter to compute in any case this relative stability term. This, then, is the true quantitative measure of the character of the effluent. An effluent having a complete relative stability has within itself the necessary oxygen reserve to complete its own oxidation. It will, therefore, abstract nothing from the stream. One having a 50 per cent relative stability has one half as much oxygen as it will eventually require. It will, therefore, abstract from the stream as much oxygen as it already contains. In this way one can determine in advance the effect of the discharge of any particular kind of effluent into a given stream and can specify in definite quantitative terms the character of effluent which may be discharged into the stream without fear of nuisance.

This relative stability number as it has been worked out for various types of effluents is defined by the following formula:—

$$S = 100(1 - 0.794^t)$$

S is the relative stability number in per cent and t the time of decolorization at 20°. Temperature has an important effect upon all bio-chemical reactions and in this case it was found that the velocity was doubled between 20° and 37°; therefore, at 37° the formula becomes:—

$$S = 100(1 - 0.630^t)$$

This latter temperature may be used where quick results are required, but since in this case the bacteria at work are not those ordinarily working in the stream, the 20° temperature should be used in important investigations, or it should at least be employed to check the 37° results. If necessary a new 37° formula should be derived. Observations of the samples need not be made more frequently than every twelve hours, nor continued beyond four days in routine work. For very careful work a ten day period of observation will be necessary. In practice, however, it has been found sufficiently accurate to average all results over four days at 20° at a lump figure of 95 per cent.

From the 20 formula the following values are taken for convenience:—

Reducing time t	Relative Stability S%	Reducing time t	Relative Stability S%
0.5	11	8.0	84
1.0	21	9	87
1.5	30	10	90
2.0	37	11	92
2.5	44	12	94
3.0	50	13	95
4.0	60	14	96
5.0	68	16	97
6.0	75	18	98
7.0	80	20	99

The establishment of a quantitative basis for stability measurement was an important step but the matter was still in an incomplete stage. Relative stability in an effluent is capable of interpretation in terms of oxygen requirement but only indirectly. In a sewage devoid of oxygen there is no relative stability, yet sewages differ in putrescibility and the differences should be measureable.

Before proceeding with calculations of the effect of a given discharge of sewage upon a stream, two things must be known, the available oxygen of the stream and the oxgyen requirements of the sewage.

The former is not always determinable but may generally be approximated. Our present discussion is concerned with the latter. This is the one fundamental value upon which the calculation must rest. It must not be relative to anything, but stated specifically, in milligrams per liter, the oxygen requirement.

In an effluent the result is obtained as follows:—

Relative stability,	75%
Oxygen available, free and as N_2O_3 and N_2O_5,	10 mg. p. lit.
Oxygen requirement,	$(10 \div .75) - 10 = 3.3$ mg. p. lit.

In a sewage two methods of treatment are available:—

A. The sewage is diluted in tap water in a suitable ratio, say 10% of sewage; the oxygen of the water being known. Methylene-blue is added as usual and the time of decolorization noted. This gives the relative stability of the mixture, from which its oxygen requirement can be obtained as above. The oxygen requirement of the whole sewage is ten times as great as this value.

Theoretically this gives the total oxygen requirement. Such is the nature of the reaction, however, that even in an excess of oxygen, only about half this requirement is utilized in four days. Under most conditions such a period of time suffices to carry the water to the sea or to a much larger stream with consequent greater dilution. The time element therefore must be considered. The rate of oxidation, or the total requirement in a specified time is necessary for a complete solution.

Here once more recourse is had to the known facts of physical chemistry. In a sufficiently dilute solution of sewage and aerated water, the oxygen withdrawn from the water during a specified period of time can be directly measured by determination of the oxygen present initially and after a definite time, say 24 hours. If the reaction be monomolecular with reference to the oxygen, as appears to be the case, we have $\log. O - \log. o = KC^nt$.

Here O is the initial and o the final dissolved oxygen value, C the concentration of sewage, expressed in per cent by volume, t, the duration of the test in hours, and n, a concentration exponent, K is the velocity constant of the reaction to be determined. With K known the calculation may be reversed and with the initial oxygen of the stream, O, and the concentration in the stream, the final result, o, may be determined at the expiration of any time. In dealing with effluents and with many sewages the exponent, n, was found to be unity and was omitted. Later work showed that this was not universally true and Lederer has since shown a considerable deviation in some cases. The value of n, however, is usually constant in any given case and may be determined by the proper study of a series of dilutions. If n be not constant in the particular case under consideration, then this formula is of less general nature and the concentration or dilution in the test must be made to conform approximately with that in the stream. Under these conditions the effect after any stated period of time of the discharge of any volume of sewage into a stream of known volume and oxygen content is determinable.

This method of study has proven of great value in studies of New York Harbor and of the probable effect of partial purification; of concentration of the discharge at certain points; and of the addition of more sewage through the proposed Passaic Valley sewer.

Finally these methods permit for the first time the adoption of rational specifications for sewage effluents. This may be illustrated by an example. Let it be assumed that a certain body of water is the necessary final place of discharge for the sewage of a definite future population. A wise treatment of the problem by the state authority would involve the determination of the capacity of the body of water to receive sewage without danger of a nuisance. Questions of bacterial pollution are incidental and can be treated separately. The sewage may if necessary be disinfected without further treatment. Suspended matter, visible effects and deposits are also capable of separate treatment. With these matters settled there remains the question to what extent can the waters be utilized to carry on the work of purification. Let the oxygen capacity of the water be divided pro-rata among the various populations, present and prospective, unless there be some strong economic reason for favoring one center of population, as there is in the case of lower New York City. Then each community may have for its own use its share of this oxygen. New works may be authorized with the specification that the effluent shall have a total oxygen requirement, in a definite number of days, not exceeding a definite value, expressed in pounds per day. This requirement is determined by the method outlined, the value found in milligrams per liter being multiplied by the total discharge in liters per day and converted into pounds. The sum of all these amounts must not exceed the capacity of the water, and small growing communities will not at once be burdened with expensive works. Neither will any community be put to an unfair expense for excessive and disproportionate purification as so often happens at present. It would be the duty of the state authority to warn the community from time to time of the state of its oxygen appropriation, and to estimate at what date partial purification should be begun. In this way towns and cities will be permitted to take advantage of the rapid improvements in the art of sewage disposal and incentive will be given to further studies in cheap, partial purification methods, which at the present day are so essential to the successful solution of the sewage disposal problems in large cities.

In this day of conservation and efficiency it remains for the investigator in the underlying bio-chemical principles of sewage purification to point out a safe middle course between the autocratic and often unduly severe requirements of state authority on the one hand, and, on the other, the almost criminal destruction of the invaluable natural resources of our waters.

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THE CHEMICAL DISINFECTION OF SEWAGE

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Before an association of public health officials it will be unnecessary for me to dwell at any length upon the eminent desirability of some kind of sewage disinfection. Sewage, representing as it does, the wastes of modern community life, is the very embodiment of the idea of uncleanness and of unwholesomeness. It may contain at any time highly infectious material, and probably does at all times carry germs capable of setting up abnormal processes in human beings. In earliest historical times these facts were recognized and provision for the proper disposal of excrement was accordingly made. Some time after the advent of sewers, the real problem of sewage disposal made itself felt, and early attempts at sewage purification were made with the primary idea of destroying in the sewage its power to communicate disease—that is, to disinfect it.

One of the most successful of these attempts was the sand filter, a device which needs no introduction before a Massachusetts audience. This state is the home of the sand filter, and through the activities of the State Board of Health, extending back over the past twenty-four years or more, it has been brought to its present high degree of efficiency. The sand filter did its work well and could be relied upon to remove a very large percentage of the sewage bacteria. In addition to this it purified the sewage so thoroughly that in appearance, in taste, and in all other ways by which one ordinarily judges, a pure drinking water resulted.

Unfortunately the use of this excellent device is limited to those smaller communities which are situated near natural sand areas. Cities of the Middle West and of many other parts of this country have for the most part no such good fortune as is ours in Massachusetts. Even here the necessary land cannot always be found, and it is becoming more and more difficult each year to find suitable sand areas in the neighborhood of the cities. Where, for example, could Boston find the thousand or more acres of sandy soil which would be required for the treatment of the sewage of the city proper? The limitations of this process have led investigators in many countries to seek improved methods of purification requiring smaller areas of land. Particularly in England has this been the case, and there have resulted two processes known respectively as the contact bed and the trickling filter. It will be unnecessary to go into the details of these processes at this ti[illegible] further than to state that a modern trickling filter treats sewage at a rate [illegible]nty or more times as great as the permissible rate of the old sand filter. The results, however, are far less perfect, and especially in the matter of removal of bacteria these rapid filters leave much to be desired. Sewage purification in fact and especially up to a few years ago, had come to be looked upon as a means of depriving sewage of its offensive characteristics, of its tendency to putrefy, but not of its bacteria. This is a somewhat debatable point and there may be some exception taken to such a

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ment, but it is the writer's belief, founded upon somewhat extensive observation and experiment, that a fifty or sixty per cent. removal of bacteria is about all that can be obtained in actual practice by a trickling filter, working under practical conditions upon the sewage of a city.

This half-way measure, judged from a bacterial standpoint, has been forced upon us by the necessities of the situation, and, were it not for the possibilities of chemical disinfection, the purification of sewage by the only practical means available for our larger communities would not constitute a material improvement in stream conditions, viewed solely now from a bacterial and sanitary standpoint.

A further and still more important reason, however, for taking up the study of chemical disinfection, results from the common practice of discharging sewage into rivers or other bodies of water without treatment. However, as sanitarians, we may deprecate such practices, and however earnestly we may labor to make better conditions possible and, in consequence, enforcible, the fact remains that biological sewage purification with all the advances of the past decade is still beyond the reach of most large cities. The reason for this is not so much the expense involved as the great difficulty in securing proper locations for disposal works. It happens, fortunately, that the large centers of population are generally located upon large rivers or upon the seaboard, where there is water enough to dilute the sewage so that no obvious physical nuisance results. There remains, then, only the danger incident to the discharge of disease germs, with a possibility that these germs may reach public water supplies, shell-fish areas, or bathing beaches, or otherwise become a source of infection.

The Merrimac River will serve as an excellent illustration. The sewage of Lowell, the largest city on the river, is discharged without any attempt at purification into the water supply of Lawrence, the next largest city, and Lawrence and the cities below, in their turn, discharge their untreated sewage into the same stream. At the mouth of this river is located one of the largest and most productive soft clam areas of the state, an area from which clams are taken throughout the year for shipment to many parts of this country.

The physical capacity of the waters of this river to receive and dispose of sewage without nuisance, although utilized to about its natural limit, has thus far proven sufficient or nearly sufficient for the burden thrown upon it. Fortunately, also, Lawrence filters this water before drinking it. But the margin here is too narrow. Instances are not lacking in this and similar cases where deaths have resulted from a failure of the water filte properly perform its task. Moreover, no similar safeguard can be thrown about the shell-fish industry. A recent study of the situation, undertaken on behalf of certain Boston wholesale dealers, convinced the writer that clams from these areas were probably unsuited for human consumption, and could not be used by these dealers in their interstate business without incurring the danger of federal seizure and prosecution, in which event no successful defense could be maintained.

This example is merely cited as an illustration of the desirability of sewage tion in general, and of disinfection or the destruction of germs in particular; and the whole subject of thedesirability of disinfection has been considered rather extensively because, with our present simple methods of procedure, it is more difficult to determine when disinfection is called for than it is to say how it may be accomplished.

Turning now to the methods of disinfection, one finds a history that is varied and interesting. Long before the general acceptance of the germ theory of disease, chemical methods of sewage purification were recommended and used. Deodorization and the prevention of offensive putrefaction, believed at that time to be disease producing, were the purposes chiefly in view.

Later, in 1889, the Webster electrolytic process was proposed, primarily as a means of clarifying sewage. It was pointed out incidentally, however, that a great reduction of bacteria took place. After this came many electrolytic processes in which either the sewage itself was electrolyzed between plates of iron, or sea water was thus treated and later added to the sewage. In Germany, the use of hypochlorites was proposed as an emergency measure at times of epidemics, but German experiments, as well as those made later by Rideal at Guilford, England, indicated excessive costs, a feature which has always been a barrier to the introduction of chemical disinfection methods.

This was the condition of affairs when investigations were begun at the Institute of Technology Experiment Station, in the Spring of 1896. Recognition of a rather curious fact in bacteriology contributed to the final successful outcome. It was known to bacteriologists that in any process of killing bacteria, whether it be by heat, cold, chemical action, or other unfavorable conditions, the bacteria do not all die at once. They behave much as soldiers would if exposed in a body to a disastrous artillery fire. The mortality at first is great. Then it becomes less and less as the number of living decreases. The percentage mortality is as great up to the end if the marksmanship is equally good, but the actual death rate becomes smaller. Obviously now, if the enemy wished to conserve his powder and lead there would come a time when it would not pay to continue the firing for the sake of bringing down the few survivors. Chemical disinfection is exactly parallel. To kill all the bacteria requires very strong doses of disinfectant and long time of contact. To kill 99% of them might require half as much or one-third as much and corresponding shorter time. The practical question before us was, therefore, not how much disinfectant is required to kill *all* the bacteria, but how great a result can be achieved by the use of quantities which we can afford to employ. Perfection, however desirable, is hard to attain. How nearly can we reach it without making the process so costly that it will be impracticable?

Several disinfectants suggested themselves for trial and a thorough review of the whole subject was undertaken. The details of this investigation have all been published elsewhere, and it will be unnecessary to burden these pages with them. Suffice it to say, that the question came down to two classes of disinfectants—copper compounds and chlorine compounds. The one, a poisonous metal, acts like mercury and other heavy metals; the other, an oxidizing agent, is the active constituent of ordinary chloride of lime or bleaching powder. Of two, the chlorine compounds proved themselves by far the more efficient, and of the several forms of chlorine, ordinary chloride of lime—more properly hypochlorite of calcium—produces better results for the money than any other.

The amount necessary varies greatly with the character of the sewage or effluent. The stronger the sewage, the greater the amount required. Crude Boston sewage requires on the average about five parts per million of available chlorine, or 125 pounds of bleaching powder per million gallons for a bacterial reduction of 99%. Twice this amount gives a reduction of 99.9%, which illustrates the mortality law described, or the increasing difficulty of killing the few remaining bacteria. Filter effluents of the kind described earlier in this paper, the trickling filter effluents, require for the same degree of disinfection, two or three parts of chlorine per million; that is, 50 to 75 pounds of hypochlorite per million gallons.

Without describing the necessary engineering structure for adding and mixing the disinfectant and for storing the sewage during the short time required for the action to proceed, it is sufficient to state here that they are relatively inexpensive and require comparatively little space. The disinfectant is added in solution, at a rate which is proportioned to the flow of sewage and the sewage effluent is then passed through tanks which hold it for from half an hour to two hours, according to circumstances.

One further detail of these investigations calls for comment. These bacteria which we enumerate in routine examination are of course for the most part harmless. There are thousands of them in every drop of sewage, and the pathogens, the real agents of disease, are so comparatively rare in this motley throng, that we cannot pick them out with any degree of certainty. It might easily be argued therefore that there is no evidence thus far that the pathogens are killed at all. May they not be the one per cent. of survivors? If so, our work would be of no avail; disinfection would not disinfect. This is a hard problem to solve as is readily seen. It was attacked in this way. In all our tests, in addition to the regular enumeration of bacteria, we determined separately the numbers of the bacillus coli, the common inhabitant of the human intestine. This organism, like the others, is harmless but it gave us something to tie to. The colon bacillus was killed at about the same rate as the others; a little more completely if anything. Next we took a pure culture of this organism in water, and side by side with this a similar pure culture of the typhoid germ. These two cultures were treated with a series of varying strengths of the hypochlorite and the death rates determined under a wide range of conditions. The results were practically identical in the two cases and showed that the coli results may be accepted as safe criteria of the typhoid results.

Turning now from experiment to experience, what have been the results? Some of the original experiments were made at Baltimore for the Baltimore Sewerage Commission. At Baltimore the sewage of the great system that is now nearing completion will be purified to the highest practicable degree for the sake of the valuable oyster industry. There it was proposed to install trickling filters and follow these by sand filters. Disinfection was later substituted for the sand filters in the plans of a saving in initial cost of about a million dollars and in annual operation of over twenty-five thousand dollars. This system is now approaching completion, and while it is thought possible that no after-treatment may be required, the simplicity of chemical disinfection makes it possible to install it at short notice, and it will be installed if it is found necessary.

In New Jersey the State Board of Health took an active interest in the process from the start and aided in the preliminary experiments at Red Bank, New Jersey. Disinfection is strongly advised by that Board and in many places where drinking-water streams or shellfish interests are at stake, insisted upon. There are at present five or six plants in operation there, others are being designed, and still others have provision made for disinfection if it should prove desirable.

The most important installation of this type, however, is at Providence, R. I., where twenty million gallons of sewage a day are being disinfected with most satisfactory results. Examinations of the oysterbeds this Fall, previous to certification by the State Commission of Shell-Fisheries, showed that many acres of beds that were condemned a year ago can now be certified under the rigid standards of that Commission and that the dead line for oysters has moved a long way up the Upper Narragansett Bay, a result due without doubt to the disinfection treatment.

Lastly, an interesting and far-reaching effect has been the application of this process to water. It was stated that the purer the sewage or effluent, the less hypochlorite would be required. This principle has been extended with greatest success to the field of water purification. Veritable homeopathic doses are sufficient in this case and several hundred American cities, including the two chief cities of Canada, are now regularly using disinfected water. As an emergency means for rapidly controlling typhoid fever epidemics it has on many occasions proved of greatest value. We have at the Institute an emergency outfit by means of which, within twenty-four hours, any small water supply can be properly disinfected and all danger from typhoid fever eliminated as far as the water supply is concerned.

Chemical disinfection of both water and sewage has thus justified itself both experimentally and practically. It was said two years ago by an eminent and disinterested authority that a new epoch had been begun in both these fields. Subsequent developments have proved the correctness of this prophecy. It is now possible to raise a new and exceedingly effective barrier between the wastes of one community and the food and water supplies of another. The adequacy of this barrier is proven. Its usefulness depends upon the extent to which it shall be employed and this in turn rests with those who are officially charged with the protection of the public health.

If, by the results of these investigations, which have been but briefly recounted here, the use of our streams for carrying off the unpurified filth of cities, is made a little more reprehensible because a little less excusable, then the time, the money, and the effort that they have entailed will not have been spent in vain.

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EXPERIMENTS ON DISINFECTION OF WATER WITH ULTRA-VIOLET LIGHT, WITH A DISCUSSION OF THE LAWS OF DISINFECTION.*†

Maurice R. Scharff.[1]

INTRODUCTION.

The value of sunlight in human dwellings as an aid to healthy living has been recognized from involuntary human experience from time immemorial. The actual germicidal effect of light has been a subject of study ever since 1877, when Downes and Blunt,[2] in a classic series of experiments, demonstrated that light inhibited bacterial growth, and that the blue end of the solar spectrum was the more efficient for this purpose. A host of investigators studied the phenomenon in the eighties and nineties, some turning to the electric arc as a source of bacterial light, and a group, headed by Finsen, made the first application of the phenomenon in the treatment of certain forms of tuberculosis with the Finsen lamp. It was not until within a few years, however, that the invention of the quartz tube mercury arc lamp, and an awakened interest in water disinfection gave impetus to the study of water disinfection with ultra-violet light.

Curiously enough, the first work of this kind appears to have been done on milk. An anonymous communication to *Die Milchzeitung* (1909) states that Privatdozent Max Seiffert invented an apparatus for sterilizing milk with ultra-violet light in 1901. And Billon-Daguerre[3] (1909) in a communication to the Académie des Sciences, dated January 7, 1907, claims priority in the invention of a similar method.

The first published account of experiments in disinfection of water with ultra-violet light are by Courmont and Nogier[4] (1909). They have been closely followed by many others, including Billon-Daguerre[5] (1909), Henri, Helbronner, and de Reckling-

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[2] *Proc. Roy. Soc.*, 1877, 26, p. 488; 1878–79, 28, p. 199; 1886, 40, p. 14.

[3] *Compt. rend. Acad. d. Sci.*, 1909, 148, p. 542.

[4] *Ibid.*, 147, p. 523.

[5] *Ibid.*, 149, p. 810; 1910, 150, p. 479.

hauser[1] (1910), Gabriel-Vallet[2] (1910), Urbain, Scal, and Feige[3] (1910), Cernovodeanu and Henri[4] (1910), and Grimm and Weldert[5] (1911).

These observers have reported disinfection or sterilization of water with current consumptions varying from 75 to 900 kilowatt hours per million gallons. Others have studied the chemical effects of light on air and water, and still others have determined spectrographically which light waves are most effective in this respect. There has been a notable lack, however, of any satisfactory quantitative measure of the effect of varying such factors as distance, absorption, etc., and hence no working hypothesis suitable for the rational design of an apparatus for disinfecting water. It was with a view to determining whether or not these deficiencies could be supplied that the studies on which this paper is based were undertaken.

ON THE STANDARDIZATION OF DISINFECTANTS.

Previous attempts to estimate the disinfecting value of light under varying conditions have been based on the time required for complete sterilization of a given quantity of liquid. Such a measure, however, would be of no value for designing a disinfecting apparatus; for in such an apparatus the water would necessarily be moving, and could not be kept under constant conditions until sterilized. Moreover, anyone familiar with the typical curve of disinfection (see Fig. 1) must recognize that the intersection of its flattest part with the horizontal axis must be difficult to determine with any accuracy whatever, and that any method of standardization based on such a determination must be unsatisfactory, even if there is any simple relation between this time and the bactericidal efficiency of the disinfectant. Cernovodeanu and Henri[6] (1910) attempted to use this procedure, with the following results:

TABLE 1.

Distance	Time Necessary for Sterilization	
	110 v. Lamp	220 v. Lamp
cm.	Seconds	Seconds
60	300	30
40	180	15
20	20	4
10	4	1

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[1] *Compt. rend. Acad. d. Sci.*, 1910, 150, p. 932; *ibid.*, 151, p. 677.

[2] *Ibid.*, p. 1076.

[3] *Ibid.*, 151, p. 548; *ibid.*, p. 770.

[4] *Ibid.*, 150, p. 52; *ibid.*, p. 549.

[5] *Sterilization von Wasser mittels ultravioletter Strahlen*, Berlin, 1911.

[6] *Loc. cit.*

They concluded that there is no simple relation between time of sterilization and distance, and pointed out that the time varied more rapidly than the square of the distances.

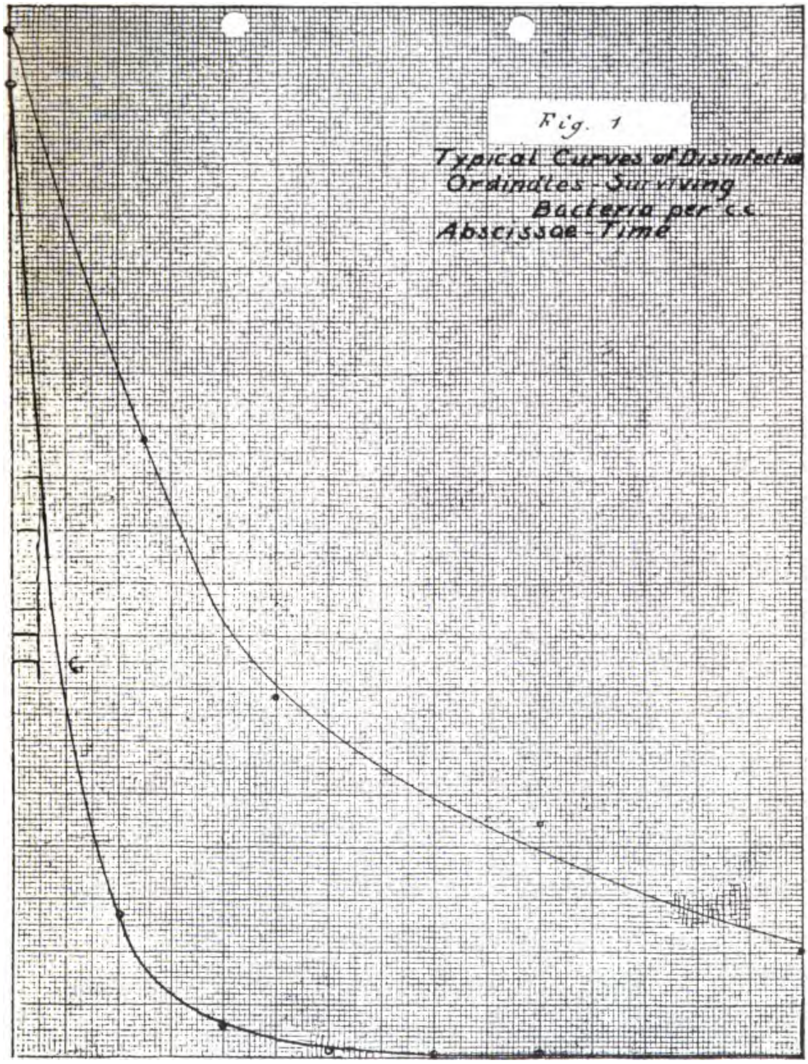

Fig. 1

Typical Curves of Disinfectio
Ordinates - Surviving
Bacteria per c.c
Abscissae - Time

More applicable to the practical problem would be a measure of the instantaneous effect—the rate of disinfection. And such a method has been proposed for chemical disinfectants as a result of studies inspired by the observations that disinfection is always an orderly process with respect to time, and that the curve of disinfection is always of the same general type (see Fig. 1). In 1907 and 1908, Madsden and Nyman,[1] and Chick,[2] working simultaneously but independently, demonstrated that, in the disinfection of anthrax spores by chemicals, the logarithms of the numbers of living spores varied inversely as the time. Both concluded that, in the case of anthrax spores, the disinfection proceeds in the same manner as a monomolecular chemical reaction—in other words, that the rate of disinfection varies directly as the number of surviving spores. This theory has been developed and elaborated by Phelps[3] (1911) and supported by additional experimental evidence by Chick[4] (1910).

The mathematical form of this law is $\frac{dN}{dt}=kN$ where "N" is the number of living bacteria in a unit volume. Integrating between times t_1 and t_2, $\log\frac{N_2}{N_1}=k(t_2-t_1)$, and the accordance of the law with the facts will be represented by the degree of constancy of experimental determinations of $k=\frac{\log\frac{N_2}{N_1}}{t_2-t_1}$.

The experiments of Madsden and Nyman[5] (1907) on disinfection of anthrax spores with mercuric chloride, those of Chick[6] (1908, 1910) on disinfection of anthrax spores with phenol, and a few of her experiments with *B. typhosus*, *B. coli*, and other organisms, show remarkable agreement in the values of the constant obtained. But in the great majority of Chick's experiments on vegetative cells, in her analyses of those of Kronig and Paul,[7] and of Clark and Gage[8] (see Chick, *Jour. Hyg.*, 1910, 10, pp. 239–80), and in 10 of my own experiments, a gradual decrease in the constant, often of very great magnitude, was noted with increasing values of "t." As examples, I quote below values obtained from one of Chick's experiments, and from one of my own. Chick has used common

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[1] *Ztschr. f. Hyg.*, 1907, 57, p. 388.

[2] *Jour. Hyg.*, 1908, 8, p. 92; p. 655.

[3] *Jour. Infect. Dis.*, 1911, 8, p. 1.

[4] *Jour. Hyg.*, 1910, 10, p. 237.

[5] *Loc. cit.*

[6] *Loc. cit.*

[7] *Ztschr. f. Hyg. u. Infektionskr.*, 1897, 25, p. 1.

[8] *Rep. State Bd. Health*, Massachusetts, 1903, 34, p. 268.

TABLE 2.

DATA TAKEN FROM CHICK (1908), TABLE IX, P. 108.

TIME (MINUTES)	NUMBER BACTERIA IN ONE DROP OF DISINFECTION MIXTURE	VALUE OF $K=\frac{\log \frac{N_2}{N_1}}{t_2-t_1}$		
t_2		$t_1=0$	$t_1=5$	$t_1=10$
0	25,250	....	....	....
0.5	540	3.74	....	....
1.0	305	1.92	0.50	....
2.1	97	1.15	0.47	0.45
3.1	50	0.87	0.40	0.37
4.1	24	0.74	0.38	0.36
5.2	10	0.65	0.37	0.35
7.0	2	0.57	0.36	0.36, etc.

or Briggs logarithms in all her work. I follow her in quoting her results, but in all my calculations, based on my own experiments, natural or Napierian logarithms are used.

TABLE 3.

DISINFECTION OF B. COLI WITH ULTRA-VIOLET LIGHT FROM MAGNETITE ARC AT 20 CM. DISTANCE.

TIME (SECONDS)	NUMBER BACTERIA PER C.C.	VALUE OF $K=\frac{\log \frac{N_2}{N_1}}{t_2-t_1}$			
t_2		$t_1=0$	$t_1=2$	$t_1=4$	$t_1=6$
0	185,000	....	....	....	.....
2	27,100	0.96	....	....	.....
4	5,950	0.86	0.76	....	.....
6	1,020	0.87	0.82	0.88	.....
8	990	0.65	0.55	0.45	0.015
10	880	0.54	0.43	0.32	0.037
15	420	0.41	0.32	0.24	0.099
20	211	0.34	0.27	0.21	0.11

It is significant that this change is always in one direction, and its regularity, when K values are plotted against time, suggests at once some controlling law. Chick recognized this and comments,[1] "The decrease in the value of K in the case of *B. paratyphosus* is a regular and orderly one. If values of K are plotted against numbers of surviving individuals, a continuous curve is obtained, showing that the value of K is altering in accordance with some law, and bears some relation to the number of surviving bacteria." In 1910 she made a similar comment,[2] and suggested that this deviation was connected in some way with variation among the bacteria, with respect to degree of possession of the property that causes disinfection to run logarithmically.

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[1] *Jour. Hyg.*, 1908, 8, p. 109.

[2] *Ibid.*, 1910, 10, p. 282.

Following the line of this plausible suggestion, so much more in accordance with biometric experience than a theory based on equal possession of any natural property, I have developed the logarithmic theory of disinfection, assuming that any bacterial culture contains cells with varying K values, and that their distribution with respect to this property accords with biometric experience—namely, that there is a concentration of numbers about some mean or modal value, with smaller and smaller numbers departing extremely from this mode.

As a mathematical basis for this theory, two groups of curves were studied, both of which have been shown by biometricians to bear a strong general resemblance to the plotted curves of distribution of individuals with respect to biological characteristics. One, $y=Ce^{-h^2(k-a)^2}$ (see Fig. 2), is the "curve of error," representing the distribution of the errors of experimental observation. The other family, $y=C\left(\frac{k}{a}\right)^n e^{-h^2\left(\frac{k}{a}\right)^2}$ (see Fig. 3), is a group of which the member where $n=2$ is the curve representing the distribution of errors of mean square, and is the basis of Maxwell's kinetic theory of gases. In both cases, "a" is the value of "k" at the mode, and the area under any portion of the curve represents the number of organisms having "K" values between those corresponding to the limiting ordinates.

Without discussing the relative merits of these two sets of curves, or presenting the mathematical study that was made of both, it may be said that no analytical solution of either was found after several weeks' work. And while it was shown that solutions of the former by trial and error, and of the latter by a graphical method, are possible, neither could be worked out without a great amount of labor. Only a very few values were obtained in this way, not enough to determine whether or not such values would show any greater constancy than the "K" values previously discussed. It was demonstrated, however, that, in both cases, $\lim\limits_{t=0} \frac{\log \frac{B}{b}}{t} \quad Da$, where "$B$" is the initial number in a unit volume, "b" is the number surviving in a unit volume after time "t," "a" is the modal value of "K" at the beginning of the disinfection, and "D" is a constant for the culture independent of the kind or concentration of the disinfectant. (For this demonstration, one assumption was

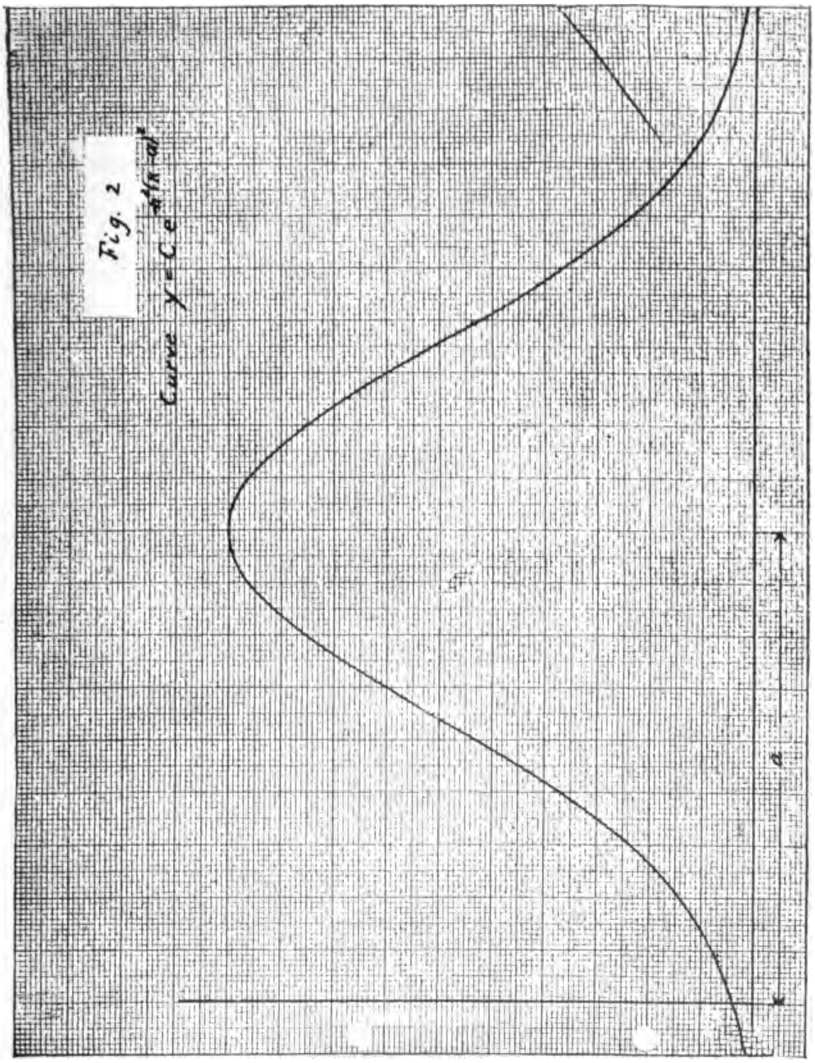

Fig. 2

necessary, viz.: that the relative proportion having "K" values greater than the mode will be the same, whatever the absolute value of "a.") It is therefore possible to obtain the ratio of "a" values (D canceling out) for different disinfectants, or for different conditions, by plotting $\frac{\log \frac{B}{b}}{t}$ against time, and extending the curves to intersect the axis $t=0$. As "a" represents the rate of action of the given disinfectant upon a specific organism, and not a composite value for a mixture of varying ones, it is reasonable that this ratio should represent a truer measure of the relative efficiency of the disinfectants, or of the same disinfectant under varying conditions, than the mean of the "K" values proposed by other investigators. And the constancy of "K" in the experiments on spores fits in with the theory through the reasonable explanation that there must be considerably less biological variation between the inert, resting cells, than between active, vegetative cells, carrying on a greater variety of processes and subjected to a greater number of selective influences.

EXPERIMENTAL.

All the experiments made in this investigation were carried on with a laboratory stock culture of *B. coli.* A standard loopful was transferred every day to a tube of peptone, and a two-day old culture was used, except in one or two experiments. In general, the numbers in the two-day culture were reasonably constant, and between 100,000,000 and 200,000,000 per c.c., and a 1/1000 dilution in sterile water was used for the experiments.

Two sources of light were used. A magnetite arc without a globe, loaned by the Edison Electric Illuminating Co., of Boston, was connected with the 110 v., direct current circuit, and took about 6.6 amperes, on the average.

The other lamp was a Westinghouse-Cooper Hewitt quartz tube mercury lamp, made by the Westinghouse-Cooper Hewitt Co., of Paris, and loaned by the Cooper-Hewitt Co., of New York, for this investigation.

The lamp had a luminous tube about 12 cms. long and was connected with a 220-volt direct current circuit. The voltage was cut down by interposing a resistance to 200 volts, and the lamp took, on the average, about 4.2 amperes.

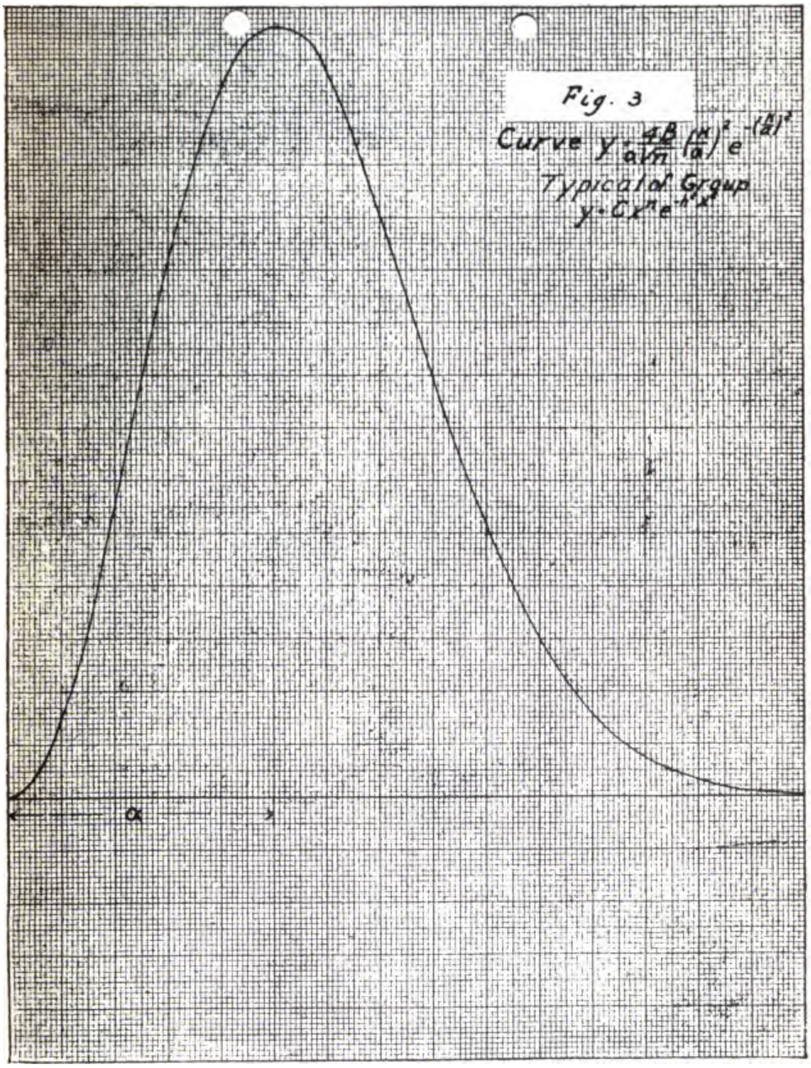
Fig. 3

The procedure finally adopted was as follows: About 1.2c. c. of the 1/1000 dilution of the culture was pipetted into a quartz test tube, $\frac{3}{8}$ inches in diameter by about 3.5 inches long. The lamp was lit, and the tube suspended in a ring in the proper position, and screened from the light with a slate screen. A test was started by removing the slate screen quickly, and it was ended by throwing a switch and cutting off the lamp. Where it was impractical to

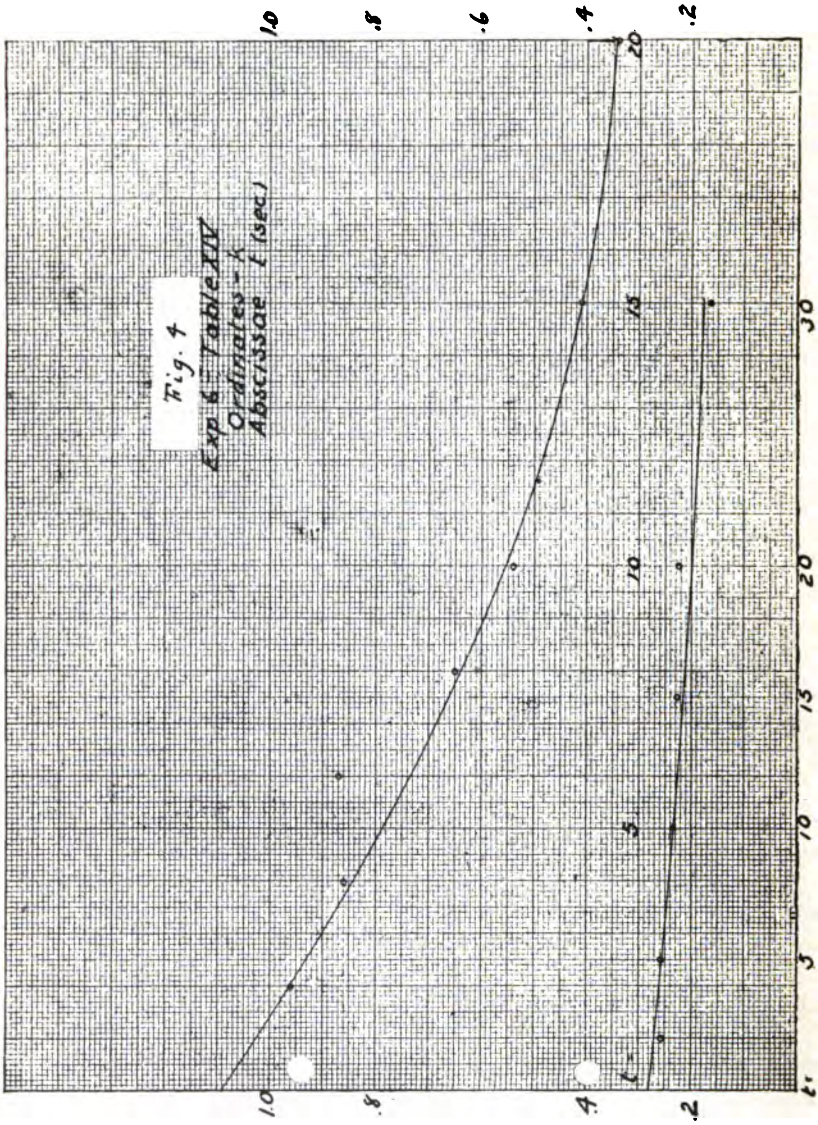
Fig. 4

interpose the screen between the lamp and the tube, the tube was screened and held just above the ring. The test was then started by dropping the tube through the ring, and ended as before by cutting off the lamp. As soon as the lamp was cut off, the tube was removed, its mouth sterilized in a flame, and one c.c. of its contents transferred in a sterile pipette to the dilution water, or direct to a Petri dish if it was not to be diluted. Samples were plated with gelatin, incubated at 20° for 48 hours, and counted.

After several experiments, it was thought probable that growth in the diluted culture during the experiment might interfere with the work, and the plan was adopted of keeping it thereafter in a double walled vessel, packed with ice, so that the temperature was maintained at 8–10° C.

1. *On the effect of varying distance.*—Seven experiments were performed to study the effect of varying the distance in air from the light. Of these, three gave enough values of $\frac{\log \frac{B}{b}}{t}$, showing the usual orderly decrease to allow the construction of reasonably good curves. As an example of these curves, Fig. 4 shows those corresponding to Experiment 6 below. The results of these three experiments are given below:

TABLE 4.

Expt. 6, February 12, 1911. *B. coli*, two-day peptone. Samples rayed horizontally from magnetite arc, 110 v., 6.6 amp.

Time (Sec.)	Counts	Dil.	Mean No. per c.c.	$k = \frac{\log \frac{B}{b}}{t}$
Distance 20 cm.				
0	175, 239, 140	3	185,000	...
2	238, 193, 292, 360	2	27,100	.96
4	61, 61, 53, 63	2	5,950	.86
6	135, 84, 68	1	1,020	.87
8	75, 93, 127, 102	1	990	.65
10	77, 96, 88, 91	1	880	.54
15	307, 540	0	420	.41
20	256, 158	0	210	.34
Distance 40 cm.				
0	168, 229, 251, 74	3	180,500	....
2	104, 115, 122, 90	3	108,000	.257
5	590, 487, 439, 465	2	49,500	.259
10	168, 184, 119, 165	2	17,300	.234
15	553, 524, 832, 816	1	6,810	.228
20	202, 265, 167, 180	1	2,035	.224
30	136, 132, 138, 118	1	1,310	.164

TABLE 5.

Expt. 7, February 13, 1911. *B. coli*, four-day peptone. Samples rayed horizontally from magnetite arc, 110 v., 6.6 amp.

Time (Sec.)	Counts	Dil.	Mean No. per c.c.	$K = \frac{\log \frac{B}{b}}{t}$
Distance 20 cm.				
0	309, 296, 266, 280	3	288,000	....
2	32, 36, 44, 34	3	36,500	1.03
4	74, 77, 87, 98	2	8,400	.88
6	23, 22, 28, 20	2	2,325	.80
8	72, 90, 88	1	833	.73
10	125, 126, 111, 95	1	1,140	.56
15	200, 428	0	314	.46
20	267	0	267	.35
Distance 40 cm.				
0	352, 341, 385, 411	3	372,000	.25
2	231, 242, 225, 200	3	224,500	.25
5	1060, 1060, 968, 952	2	101,000	.26
10	324, 325, 324	2	32,400	.24
15	1528, 1570, 1495, 1235	1	14,570	.22
20	456, 878, 750, 810	1	7,240	.20
30	290, 178, 171, 172	1	2,030	.17

TABLE 6.

Expt. 11, March 9, 1911. *B. coli*, two-day peptone. Samples rayed horizontally from mercury arc 200 v., 4.2 amp.

Time (Sec.)	Counts	Dil.	Mean No. per c.c.	$K = \frac{\log \frac{B}{b}}{t}$
Distance 20 cm.				
0	322, 270, 276	3	289,300	....
2	18, 22	2	2,000	2.50
4	118, 172	1	1,450	1.33
8	377, 370, 340	0	362	.81
Distance 40 cm.				
0 taken same as above	....	..	289,300	....
2	45, 57, 49	3	50,300	.87
5	156, 146	2	15,100	.59
10	615, 461	1	5,380	.40

Plotting $\frac{\log \frac{B}{b}}{t}$ against time, and extending the curves to meet the axis $t=0$, taking the intercept equal Da, we have, calling distance "L":

TABLE 7.

Experiment	L_1	Da_1	L_2	Da_2	$\left(\frac{L_2}{L_1}\right)^2$	$\frac{a_1}{a_2}$
	cm.		cm.			
6	20	1.08	40	.28	4	3.9
7	20	1.18	40	.29	4	4.1
11	20	4.70	40	1.17	4	4.0

In two other experiments it was possible to plot curves only by discarding one observation in each, which deviated extremely from the regularity indicated by the other observed values. In these cases the results were as follows:

TABLE 8.

Experiment	L_1	Da_1	L_2	Da_2	L_3	Da_3	$\left(\frac{L_2}{L_1}\right)^2$	$\frac{a_1}{a_2}$	$\left(\frac{L_3}{L_1}\right)^2$	$\frac{a_1}{a_3}$	$\left(\frac{L_3}{L_2}\right)^2$	$\frac{a_2}{a_3}$
	cm.											
8	40	.42	80	.10	..	....	4	4.2	..	...	..	...
9	20	.455	40	.195	80	.055	4	2.3	16	8.3	4	3.5

In the other two experiments, no plots of the results were possible.

2. *Relative efficiency of different sources of light.*—Two experiments were tried comparing the efficiency of the magnetite arc with that of the mercury arc. In neither case was it possible to construct "$K-t$" plots for both, and no quantitative relation was established. The experiment below, however, indicates that the mercury arc is many times as effective, although using only 1.2 times as much power:

TABLE 9.

Expt. 13, February 19, 1911. *B. coli*, two-day peptone. Samples rayed at 40 cm. horizontally from source of light.

Time (Sec.)	Counts	Dil.	Mean No. per c.c.	$K=\frac{\log \frac{B}{b}}{t}$
Magnetite arc				
0	277, 273, 314, 288	3	288,500	...
2	231, 202, 221	3	218,000	.14
5	131, 124	3	127,500	.16
20	125, 129, 132, 103	2	12,200	.16
Mercury arc 4.4 amp., 198 v.				
0	379, 400, 347, 380	3	376,500	....
2	239, 256	2	24,750	1.36
5	6, 12	2	900	1.21

3. *Absorption in water.*—Three experiments were made on the effect of interposing between the lamp and the sample various thicknesses of distilled water. A cylindrical galvanized iron tank, about 6 cm. in diameter and one meter long, and open at the top, was made, and a quartz plate about 1.1 mm. thick was set in one

end in a water-tight rubber joint, fastened between brass plates with four binding screws. The plates had a window about 2 mm. square cut out. Experiments were made by placing about 1.2 c.c. of the diluted culture in a quartz test-tube, and dropping the tube through a ring, so placed that the lower end of the tube passed through the open top of the tank into the water. The ring was at such a height that the tube was supported so as to bring the sample opposite the center of the quartz window. With this apparatus tubes could be exposed through any thickness of water up to one meter.

TABLE 10.

Expt. 20, April 1, 1911. *B. coli*, two-day peptone. Samples rayed horizontally opposite mercury arc lamp, 4.1 amp., 200 v.

Time (Sec.)	Counts	Dil.	Mean No. per c.c.	$K = \frac{\log \frac{B}{b}}{t}$
Distance 40 cm. in air.				
0	210, 225, 226, 262	3	231,000	...
2	114, 116	3	115,000	.35
4	55, 55	3	55,000	.36
6	225, 245	2	23,500	.38
Distance 22.5 cm., 2.5 in air and 20 cm. in distilled water.				
0 taken same as above			231,000	
2	155,171	3	163,000	...
5	129, 126	3	127,000	.17
10	95, 153 29, 21	2 3	18,700	.12 .25
20	18, 10	2	1,400	.25
Distance 32.5 cm., 2.5 cm. in air and 30 cm. distilled water.				
0 taken same as above			231,000	
5	136, 157	3	146,500	.092
10	107, 141	3	127,000	.060
20	289,302	2	29,600	.103
Distance 42.5 cm., 2.5 cm. in air and 40 cm. in distilled water.				
0 taken same as above			231,000	
5	212, 207	3	209,500	.020
10	164, 144	3	154,000	.041
20	98, 85	3	91,500	.046
40	27, 45	3	36,000	.047

No satisfactory plots were possible, but as a rough measure of the order of magnitude of the relation, the means of these "*K*" values may be compared, assuming the values at the same distances in air to vary inversely as the square of the distance:

TABLE 11.

Distance (cm.)	Length Water Column (cm.)	Mean Value "K"	Calculated "K" at Same Distance in Air	Absorption (Percentage)
40	0	.36	.36	....
22.5	20	.20	1.14	82.5
32.5	30	.085	.55	84.5
42.5	40	.039	.32	88.0

The quantitative results cannot be supported in accordance with the method of treatment previously adopted; but they serve to indicate that absorption is greatest in the first layers, increasing slowly with increased thickness of water.

One experiment was tried on the absorption in Boston tap water, which had a color of about 0.4.

TABLE 12.

Expt. 21, April 2, 1911, *B. coli*, two-day peptone. Samples rayed at 22.5 cm. horizontal (2.5 cm. in air and 20 cm. tap water, color 0.4) from mercury arc lamp, 4.2 amp., 200 v.

Time	Counts	Dilution	Mean No. per c.c.
0	176, 192, 205, 182 177, 161, 120, 152	3	170,000
2	175, 194	3	184,000
5	208, 170	3	189,000
10	165, 165	3	165,000
20	164, 176	3	170,000

The absorption appears to have been complete, which is in accordance with the work of Courmont and Nogier,[1] (1909) on the impermeability to ultra-violet light of water containing colloidal matter.

CONCLUSIONS.

The method proposed for measuring the bactericidal effect of a disinfectant is a reasonable one, and slight support is given to it by the fact that, for those cases in which satisfactory plots were drawn, the calculated ratios of the rates of disinfection for the modal bacteria were closely inversely as the square of the distance, or as the intensity of light. It should be noted, however, that of the 10 experiments in which it was possible to plot "*K-t*" curves, five were preliminary experiments, and five were on the effect of varying distances in air. In the absorption experiments, in those on different sources of light, and in a few others, an irregular variation in calculated "K" values, or lack of sufficient determinations, make it impossible to make satisfactory plots. Part of this may have been due to failure to make proper dilutions, through inability to predict the effect of these new conditions, and consequent loss of plates. But in some instances an ample number of points was determined, though varying so irregularly as to preclude plotting; and in a few cases an increase in the calculated values of $K = \frac{\log \frac{B}{b}}{t}$, instead of a decrease, was noted. No satisfactory explanation of these irregularities has suggested itself. Nevertheless, it is believed that the method is reasonable, and sufficiently novel and interesting to justify its presentation, not as a proved fact, but in the hope that it may lead to further study and experiment.

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[1] *Compt. rend. Acad. d. Sci.*, 1909, 149, p. 364.

Granting the reasonableness of the method, some evidence is presented that the disinfecting power of ultra-violet light varies as the intensity of incident energy, or inversely as the square of the distance. And this has some further support in the fact that the absorption in water increases very slowly with increased distance, suggesting analogy to the law that the absorption of actinic energy varies directly as its intensity. If this is true, no analytical solution of the effect on water moving toward a light can be made, for no coefficient of absorption can be determined, except for monochromatic light. It would follow, then, that no rational design of an apparatus for disinfecting water can be made, but that the machine must be constructed in accordance with certain general principles, and modified to attain maximum efficiency by experiment.

The mercury arc lamp is more effective than the magnetite arc. There is reason to believe that its efficiency may be increased by varying the voltage, and the point of maximum efficiency would have to be determined experimentally.

Disinfection by ultra-violet light would be applicable to surface waters, containing vegetable coloring matter only if the color were first removed by coagulation or filtration.

FARM WATER SUPPLIES, WITH SPECIAL REFERENCE TO DAIRY FARMS

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FARM WATER SUPPLIES, WITH SPECIAL REFERENCE TO DAIRY FARMS.

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Three types of water supplies may commonly be found upon farms. First and most numerous is the shallow well or dug well, varying anywhere from 15 feet to 40 feet or even 50 feet in depth, depending upon the amount of labor necessary to reach the water-bearing strata, and in close proximity to the house or barn.

Second in number throughout New England would probably be found the wells of similar character or springs situated at a greater distance from the buildings and with pipes leading the water directly to the buildings, either by gravity or by the use of some pumping apparatus, wind power or small engine.

A few farms are found having water supplies from the deeper sources, driven wells or artesian wells, but these are relatively rare. The character of the soil has a very considerable bearing upon the character of the water and the ease with which it may be polluted. A gravelly, open soil containing stones of varying size may offer so little resistance to the passage of organisms and materials from barnyards, drains, etc., that the water is constantly in a state of contamination. Unfortunately, this cannot be detected by taste or smell in most instances because it is only when the pollution becomes very severe and the amount of freshly decomposing organic matter relatively large that compounds would be formed by putrefactive change in sufficient amounts to give a distinct taste or odor. In fact, certain waters which are constantly polluted seem to have a particularly soft and pleasing taste, especially if the wells are of considerable depth so that the water is cold, and if, at the same time, it is clear and free from color. Should such a water supply, however, become polluted with bacteria of infectious disease, the danger from this source would be enormous, and undoubtedly many deaths from typhoid and other diseases of that character are due to this type of pollution.

In the early days when no account of the purity of the supply from the bacteriological standpoint was considered, because there was no knowledge of the bacteria themselves, the custom of establishing the water supply for a farm at the point most convenient for the users, either in the house or barn, seems to have become formulated in New England. After examination of several hundred farm water supplies, especially on dairy farms from which milk is sent to Boston, I am convinced that the consideration of the relation of the water supply to the barnyard, to the sink-drain, to the privy, or any other possible source of contamination, was rarely considered, and that the most emphasis was placed on establishing it at a point so that the amount of labor involved in carriage is the least, and the probable continuance of the supply through the year, the greatest. In many instances, therefore, wells which constitute by far the great majority of the supplies of individual farms are placed midway between the back door of the house and the barnyard, frequently on the edge of the barnyard, with no special reference to the drainage areas or drainage planes, and in such a position that if typhoid fever, or some other intestinal disease should occur in the house, the possibility of contamination of the water supply is distinctly great. While this is a condition which is found especially on old farms, it is not confined to them but may frequently be observed where the general planning out and building of an establishment has taken place within a very few years. The general plan followed in a majority of cases seems to be that of the very early days and the general assumption made that since no trouble occurred to our ancestors, no trouble can occur to us.

Of what may be regarded as the natural types of waters, namely, meteoric, surface and ground waters, there is a decided difference in the chemical and bacteriological characteristics. The meteoric waters are essentially those falling to the ground in the form of rain, snow or hail and since these are produced by the evaporation and condensation of moisture from larger bodies of water, like lakes, rivers, and the ocean, these partake somewhat of the nature of a distilled water, hence the common saying that rain water is a pure water, whereas a surface water may be very far from pure. Chemically, then, the meteoric waters are in general very soft, very low in the organic substances which we look upon as suspicious, and until they come in contact with the soil or with roofs of buildings, they contain very few of those micro-organisms known as bacteria, except the ones which are found attached to dust particles and floating in the air.

Since at the beginning of a storm these may be quite numerous, the rain falling in the early part of a shower, or the snow in the early part of a storm may be bacteriologically less free from polluting material than that which falls in the later periods of precipitation. From the standpoint of ordinary supply these may be largely disregarded, except in those instances where cisterns are provided for the collection of such waters. In New England it is not uncommon to find cisterns for the collection of rain water, not to be used for drinking purposes, but for other domestic purposes for which the softness and general purity makes it extremely valuable and satisfactory. In the south and west, however, cisterns are frequently employed for the storage of drinking water; in fact, in certain parts of the country almost the only drinking water available is that which has been conserved in this way. To safeguard, then, the character of such water it is necessary to have the cisterns or tanks properly covered to prevent infection from without, a screen to prevent the entrance of insects, such as mosquitoes, and it would probably be most advisable, if possible, to have some kind of by-pass or device by which the first water could be rejected, since this is bound to carry with it the deposits of dust, germs, and possibly more objectionable material which may collect upon roofs between storms.

The number of bacteria ordinarily found in such waters is very low. In the water falling near the end of a storm we may even find no germs since they are all carried down with the earlier fall. Such a pure water, if not contaminated later by being collected in infected or leaky cisterns, is undoubtedly very safe to use since the germs of disease are absolutely eliminated. It frequently, however, is very flat in taste or may partake of the taste of the shingles or other material over which it has flowed, but by proper aëration even rain water may become pleasing to the taste as well as of absolute safety.

With surface waters the situation is somewhat different. These are rain or snow water which has reached the ground and then by flowing over the surface has come into certain well defined water courses, brooks, rivers and ponds. The fact that the water has been in contact with the soil and that it perhaps has filtered for a small distance through the upper layers of the soil, has been sufficient to change the character of the water both chemically and bacteriologically. Chemically, those substances which are present in the soil in soluble form are taken up by the water. Consequently the chemical analysis of a surface water may vary markedly from the chemical analysis of the water before it reached the ground. Bacteriologically the same general effect is observed; that is, the water takes up mechanically particles of low specific gravity, organic matter, bacteria, etc., and we, therefore, find surface water ordinarily containing a considerable amount of dissolved and suspended material and considerable number of bacteria.

The amount and character of the dissolved and suspended material depend absolutely upon the character of the soil. In any water falling on a rich soil where nitrogenous material is undergoing decomposition we shall find the presence of the different compounds of nitrogen, free and albuminoid ammonia, nitrites and nitrates in varying amounts, depending upon the rate and amount to which the nitrification has been carried on in the soil. Similarly, we shall find the bacteria to be variable in numbers and in kinds, according to the character of the organic matter which serves them as food. A richly manured field, for example, containing organic matter in various stages of decomposition would give up to the water flowing across it or percolating through the upper layers of the soil, varying amounts of nitrogenous constituents and chlorine and possibly large numbers of bacteria, some of which might be of intestinal types or even of pathogenic types and, consequently, most undesirable.

The surface waters in densely populated regions, therefore, may be unsatisfactory for domestic purposes because of the large amount of organic matter, both of chemical and bacteriological character which find entrance to it. The germs present in the excreta of animals, both human and otherwise, are likely to occur in such a surface and when it is borne in mind that among these bacteria we may have causes of intestinal diseases or disturbances, the danger of using such water is evident. On the other hand, surface water from an uninhabited or sparsely inhabited region, especially where it is not in direct contact with richly fertilized fields, may be absolutely safe from the sanitary standpoint, because while they may contain some bacteria they would be free from pathogenic types. Occasionally waters may be found which chemically show all the marks of purity and yet which are polluted in the bacterial sense to such an extent as to render then undesirable. An instance of this sort came to my attention a few years ago in which a spring situated on a hill in a pasture was used as the water supply of a country house. Chemically, the water left little to be desired as to purity, but bacteriologically there was unmistakable evidence of pollution. Investigation showed that this spring was also used as a drinking place by cows and horses and that the intestinal bacteria found in the water were from these animal sources rather than from domestic sewage. At the same time it could never be regarded as a satisfactory condition and the water supply was, therefore, discontinued for a short time while the surroundings could be carefully freed from infecting material and fences put up to avoid repetition of the trouble.

Frequently, inspection of the source of a water supply will give all the data that are necessary to condemn, for it is evident that if drainage from privies, sink-drain, cesspools, barn yards, hog pens, or other animal quarters enters directly into the water supply it is unfit for human consumption. Then on the other hand, inspection may show nothing of the sort, while a chemical and bacteriological examination might reveal sources of pollution.

With deep wells and springs the chemical and bacteriological characteristics differ again from those of the surface waters, or shallow wells. In these cases the water has gone through, presumably, a process of natural purification by filtration. The lower stages of nitrogen compounds are oxidized in the soil by the bacteria there resident and occur in ground waters in the form of nitrates if previous pollution has taken place. The chlorine, however, would not be appreciably changed in this way. A water supply, therefore, showing high chlorine and nitrate content, but otherwise satisfactory, might easily be a purified contaminated water. Most shallow wells will show a certain amount of nitrates, especially if they are situated within a short distance of houses, barns, gardens, etc. If situated too close to such contaminating sources, the process of purification will not be complete but the water will show in addition to the nitrates, nitrites and free ammonia to some extent. The most striking evidence of all, however, is supplied by the bacteriological examination, for here we can show by direct and accurate means the exact extent to which pollution is taking place and the exact types of organisms which occur in the water. Whereas the chemical examination of a water supplies us with data which show inferentially that pollution has or has not taken place, the bacteriological examination shows us whether undesirable types of organisms are or are not entering the water at the present time.

The examination of the farm water supplies in the laboratory may be carried out by the application of the usual sanitary chemical examination combined with the bacteriological examination. To do this requires in most instances elaborate laboratory fittings and means that the samples must be shipped to a laboratory with all this equipment in order to obtain the necessary data. When we consider exactly the meaning of the information supplied by the chemical examination, we see that it is after all only another way of expressing our belief that pollution with intestinal organisms, or with undesirable material at least, has taken place or is taking place.

Without discussing here the significance of albuminoid and free ammonia, nitrites and nitrates, it is sufficient to say that these expressions convey to the trained mind, a picture, depending upon the amounts of such materials found, of a water supply receiving polluting material, or of a water supply which has in the past received such material, but is receiving it no longer. They give absolutely no information regarding the presence of undesirable types of bacteria at the moment, and it is only by an elaborate study of the relation of carbon to nitrogen that we can determine whether the polluting material was actually of animal origin or not.

By the bacteriological methods, on the other hand, we are able to show directly the presence or absence of the undesirable intestinal bacteria, and if they are found we have every reason to believe that they came only from human or at least animal sources, and that they may be accompanied by the still worse pathogenic species, such as typhoid bacillus.

Furthermore, the necessary facts as to pollution can be obtained by a bacteriological examination of the water, conducted without very elaborate laboratory facilities. It is even possible to make a house to house canvass, actually beginning the examination of the water supply of each while still on the premises, if one will take the trouble to carry sterilized culture media and the limited necessary equipment for the proper making of a few plate and tube cultures. It is true that one cannot conduct elaborate quantitative experiments in this way and that here the laboratory is an essential, but in view of the perfection to which the presumptive test for small. Unfortunately, owing to lack of data as to depth, we are unable to correlate the depths of the wells here studied with numbers of bacteria found.

In the case of springs, on the other hand, we might expect to find very low numbers of bacteria owing to the deep seating of the source of the water. It commonly happens, however, that the spring on breaking through the surface really becomes a surface pool and as such provides a favorable place for the development in considerable numbers of such organisms as Pseudomonas fluorescens, B. aquatilis, etc., so that these may frequently be found in almost pure culture. Examples of this sort are shown in supply Nos. 5, 17 and 41.

BACTERIOLOGICAL EXAMINATION OF SPRINGS.

Water supply number.	20° count.	Litmus lactose agar, 37°.	Acid formers.
1	175	7	0
2	43	2	0
3	21	1	0
4	286	11	0
5	950	0	0
6	207	0	0
7	28	7	1
8	4	2	0
9	175	7	0
10	25	4	0
11	5	2	0
12	24	2	0
13	36	6	0
14	..	2	0
15	10	0	0
16	20	5	0
17	6000	5	0
18	liquefied	23	0
19	“	5	0
20	30	2	0
21	100	20	0
22	5	1	0
23	45	20	0
24	liquefied	0	0
25	“	3	0
26	75	5	0
27	few	0	0
28	liquefied	0	0
29	8	0	0
30	63	0	0
31	10	0	0
32	175	21	0
33	0	0	0
34	226	18	0
35	2	0	0
36	300	50	0
37	171	105	7
38	liquefied	500	..
39	“	48	1
40	many	95	8
41	2040	31	4
42	..	80	5

Presumptive tests of samples 1 to 36 negative and samples 37 to 42 positive.

In case of polluted wells, the filth which constitutes the contaminating substance may gain entrance from surface wash or through cracks in the upper part of the well casing, or by cracks in the planking or other covering. Another possible method is by pollution of the bucket. The ordinary well bucket is handled by many hands and these are frequently not clean. If a person with filthy hands draws water and handles the bucket, rope or chain, the material deposited on these may gain immediate access to the well, and thus indirectly be carried from the hands of the infected person to the mouths of others who drink water from the well. When we bear in mind the possibilities of germ carriers such as typhoid carriers, etc., this becomes a serious matter.

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The bacteriological methods of examination historically followed the chemical methods of examination in development, but their directness and accuracy have, in my opinion, made bacteriological water analyses of far greater value than the chemical analyses can be.

As to what may be done to reduce the chances of infection of a farm water supply, I should recommend the following procedures:

1. Guard against contamination with human fecal matter by providing a sanitary privy in cases where water closets and well constructed cesspools are lacking.

2. See that the casing of the well is of suitable material, is tight and extends for at least a foot above the surrounding surface. It is of advantage to have it made of clay or cement to be impermeable.

3. Provide a tight top or platform so that the water cannot drip through the cracks carrying contamination from dirty boots.

4. Replace the bucket by a pump when this can be advantageously done. When it cannot, use a bucket requiring as little handling as possible or an automatic one.

5. See that the position of the well is not in the direction of the natural drainage from barnyard, sink-drain, or privy. If within 40 feet of these be sure that the soil is of good filtering material, sand, etc., and free from fissures and easy by-passes for the surface water to enter the well.

If these precautions are observed and all filth of every description is vigorously excluded, one may feel confident that the water supply will be safe and wholesome.